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STAGED OCCLUSION OF THE CORONARY ARTERIES AND STUDIES UNDER LOW OXYGEN TENSION

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INTRODUCTION

IT HAS long been the hope of investigators working with coronary artery occlusion to develop a method of gradually occluding the arteries in dogs over a period of time, thus simulating coronary artery disease in man. Various methods of occlusion have been attempted and described. These include the use of small metal bands,[1] reactive materials such as cellophane,[2] various methods of ligature,[3, 4] and several ingenious clamps.[5-8] The major difficulties with most of these methods have been the problem of gauging the degrees of occlusion of the vessel and the difficulty encountered in producing final complete occlusion. The purpose of this paper is to present a method of producing staged occlusion of the coronary arteries together with the electrocardiographic changes which occur when these dogs are placed on decreased amount of oxygen.

METHODS

Small silver clamps of the type used by Goldblatt[9] for the experimental production of renal hypertension were used (Fig. 1). During the course of a series of experiments on revascularization of the heart by means of cardiojejunopexy,[10] these clamps were applied to all major branches of the coronary arteries in a large number of dogs. The technique of gradual occlusion was

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applied in the following manner: after the chest had been opened in the anesthetized dog, the clamps were applied about the desired vessel. The vessel was then occluded to the desired amount by tightening the screw a number of turns selected to produce the desired degree of occlusion. This amounted to 3½ turns for partial occlusion with the 3 mm. clamp and 2½ turns for partial occlusion with the 2 mm. clamps. Two to four weeks later the dogs were re-operated upon, and the clamps were completely tightened. Auricular appendage amputation at the time of the original placement of the clamps facilitated later dissections.

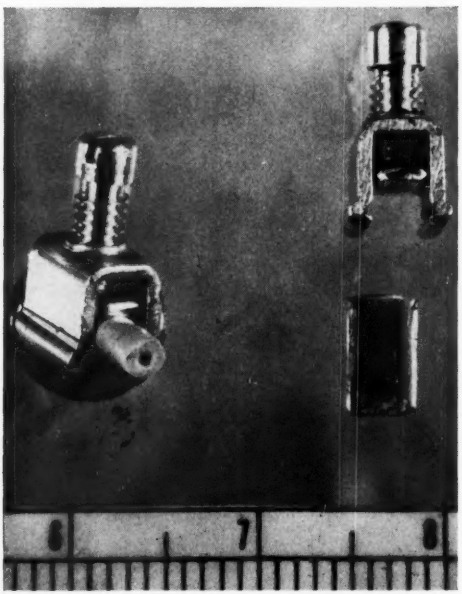

Fig. 1.—Goldblatt clamp on plastic tube simulating placement on coronary artery.

In order to demonstrate the effect of the occlusion, electrocardiograms were made, using the method of Kimura.[11] After partial or complete coronary artery occlusion was produced in 15 dogs, the effect of low oxygen tension on them was studied. This was done by taking electrocardiograms before and immediately after the animal was placed on a 10 per cent oxygen mixture for ten minutes. Post-mortem examinations of the coronary vessels were made when the animals were sacrificed or died spontaneously.

RESULTS

In a series of 15 normal dogs in which the anterior descending artery was occluded in stages as described, there were nine deaths. Six of the nine deaths occurred after the artery was completely occluded. In addition, the clamps were used on another series of 65 dogs on which cardiojejunopexies had been done.

The changes produced on the electrocardiogram by partial narrowing of the anterior descending artery were: an elevation of S-T_1 and a depression of S-T_2 and S-T_3. With complete occlusion of the vessel, these changes were usually accentuated (Fig. 2).

When placed on a gas mixture containing 10 per cent oxygen, 12 of 15 dogs with complete occlusion of one or more coronary arteries showed depression of the T wave or S-T changes (Fig. 3). Fifteen stock dogs were checked in a similar manner and only 1 showed any change in the T or S-T segment (Fig. 4).

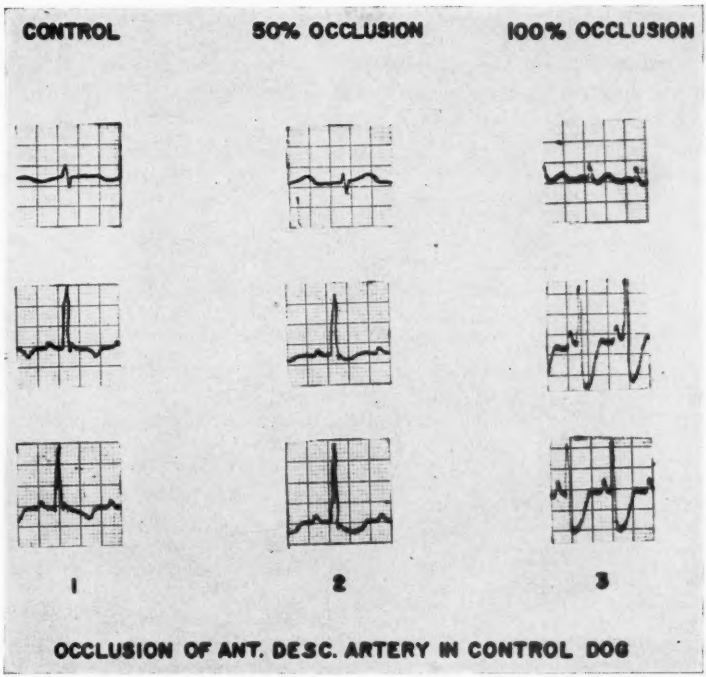

Fig. 2.—Changes produced on the electrocardiogram by partial and complete narrowing of the anterior descending artery.

Post-mortem studies after complete tightening of the clamps failed to reveal evidence of residual lumen in the coronary artery. In the normal control dogs, coronary artery occlusion with the Goldblatt clamp in stages did not significantly lower the mortality rate as compared with acute ligations.

DISCUSSION

In order to simulate human coronary artery disease more closely, it has been felt that gradual occlusion is preferable to acute coronary artery ligature. In attempts to evaluate the effectiveness of revascularization procedures, staged occlusion is especially valuable. Acute ligature may be unsatisfactory

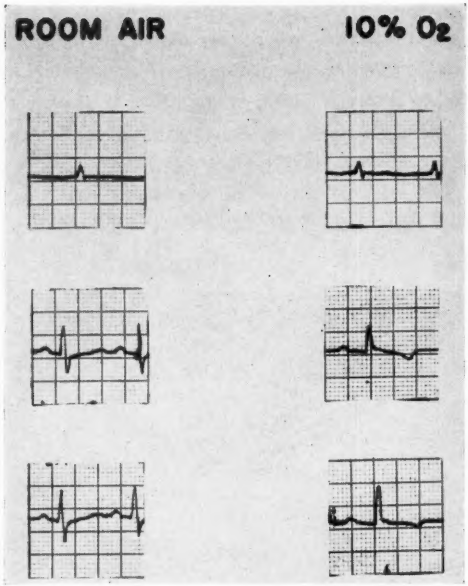

Fig. 3.—Control Dog. Changes produced in the electrocardiogram of a dog with complete occlusion of one or more coronary arteries when respired on a gas containing only 10 per cent oxygen for ten minutes.

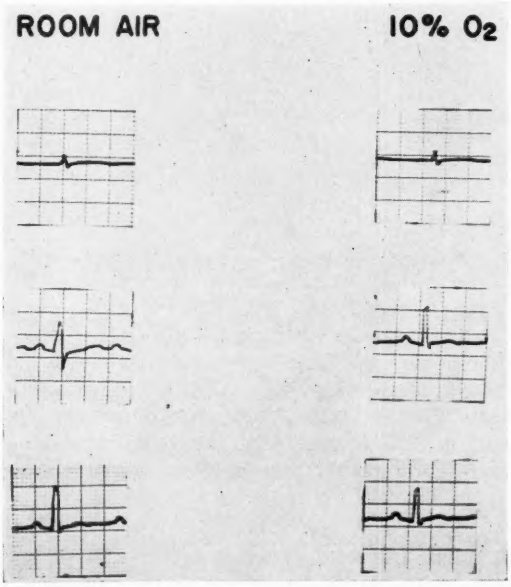

Fig. 4.—Normal Dog. Absence of changes on the electrocardiogram of stock dogs when respired on a gas mixture containing only 10 per cent oxygen for ten minutes.

as a true test of revascularization experiments, as there is no reason why collaterals that do develop should take over immediately following the acute tie-off. In addition, this method should be valuable in providing material for studies of pathologic and physiologic changes of predetermined degrees of coronary artery occlusion.

The Goldblatt clamp has been of definite value in our studies of experimental coronary artery occlusion and myocardial revascularization. The presence of the screw on the top facilitates locating the clamps at subsequent operations and also makes it possible to regulate the degree of narrowing of the artery at each stage. We feel that the use of this method of coronary artery occlusion has been a valuable adjunct in our studies of coronary artery disease and revascularization of the heart. The changes produced with anoxemia are probably similar to those produced by the anoxemia[12] or the Master two-step test[13] in the human. The anoxemia changes which are usually reversible might be exceedingly useful as a means of measuring the therapeutic effectiveness of various drugs used commonly for angina or coronary thrombosis in the human.

SUMMARY AND CONCLUSION

1. A method of producing staged occlusion of coronary arteries in the experimental animal has been presented.

2. It is felt that the Goldblatt clamp is a particularly valuable tool in the study of experimental myocardial revascularization and coronary artery occlusion.

3. Dogs with experimentally produced coronary artery occlusion quickly develop changes on the electrocardiogram when put on a gas mixture containing 10 per cent oxygen for ten minutes.

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SURGERY OF EVENTRATION OF THE DIAPHRAGM

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ALTHOUGH a gross misnomer, "eventration of the diaphragm" is the clinical term accepted by usage to describe an abnormally high position of the intact diaphragm.

This condition is a congenital abnormality and the term eventration should not be used in conditions where the phrenic nerve is paralyzed, either by a trauma, new growth, or as a result of a neuritis. The diagnosis of eventration should never be made if there is frank paradox of the diaphragm on deep, quick inspiration. The condition is still a rarity in comparison with many other diaphragmatic defects, particularly hiatal hernia, but since the inception of mass x-ray more cases have been discovered. Even so, in the last five years the Southampton and Portsmouth Mass X-ray Units have diagnosed only 32 cases in 412,000 subjects. This is an instance of 1 in 1,400 approximately. Another 6 cases have been seen independently in this Unit.

Reports of the surgical correction of eventration of the diaphragm are equally rare since less than 20 have been reported in the English literature up to 1953. Because of this, we feel that our experience of 5 patients with eventration of the diaphragm treated successfully by surgery is worth recording.

Etiology and Pathology.—We agree with Boyne-Jones (1916), Clopton (1923), and Beck (1950) that this is a congenital abnormality. Eventration results from a failure of muscularization of the diaphragm. This may be localized or the whole dome may be involved, in which case the diaphragm is represented by a thin, diaphanous membrane attached peripherally to normal muscle. In the so-called acquired eventration, such an arrangement does not exist, but the diaphragm shows a normally developed muscle and a normal central tendon; the only abnormality is that the muscle is extremely atrophic and the phrenic nerve is small, which, when faradically stimulated causes no contraction of the diaphragm. In true eventration the phrenic nerve appears normal and the muscular portion of the diaphragm contracts vigorously on faradic stimulation of the nerve and by its contraction pulls down the maldeveloped portion.

It is often stated that there are associated congenital abnormalities and that this is a point in favor of eventration being a congenital defect. In the total cases reviewed, however, this has not been so. In one case only was there an associated abnormality in the form of a foramen of Morgagni hernia.

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In our experience, a localized eventration, even though less common, is more likely to cause symptoms. Of the surgical cases, in only 1 was the whole dome involved. Of 38 cases under review, 3 only had a right-sided eventration and in 1 of these 3 the eventration was bilateral. This marked selection of the left side has been commented on by Sanford (1953) (Fig. 1).

Clinical Features.—In the series there was no disparity between the sexes; of those cases discovered by mass x-ray, 15 were males and 17 females and of the 5 patients operated upon, 3 were males and 2 were females. Eventration may be detected at any age; the range in our group was from 13 to 72 years.

Fig. 1.—A right-sided eventration is shown. On screening there was seen to be a small localized left eventration. The patient was symptom-free.

There is no definite clinical picture by which the diagnosis can be made. In the newborn, eventration may cause death from cardiorespiratory failure, which may be attributed to congenital heart disease or pulmonary atelectasis. However, it is due to a failure of the infant to oxygenate adequately because of impaired diaphragmatic movement, added to which the hemithorax may be considerably reduced by space-occupying gut. Cardiac displacement may also be present, adding to the child's difficulties (Ravitch and Handelsman, 1952). Infantile eventration may not be as frequent as was previously thought and certainly by our definition of an eventration the numbers reported are probably excessive, for example, Bingham (1954) reports 2 cases of severe respiratory distress, but both had paradoxical movement of the diaphragm and, at opera-

tion, they were anatomically normal and eventually recovered normal movement. Both babies had been breech presentations. These, of course, were not cases of eventration but of birth injuries to the phrenic nerve.

Once beyond infancy the condition tends to remain symptomless until adult life when increasing weight and raised intra-abdominal pressure may produce symptoms. All cases with symptoms had left-sided defects. These are usually gastrointestinal but there may be associated respiratory embarrassment and even cardiac distress. Six of the 38 patients presented with symptoms which were gastrointestinal and included epigastric pain, flatulence, belching, and 1 had severe melena; this patient will be discussed later. The abdominal pain may not be relieved by alkalis and is made worse by food, in contrast to the

Fig. 2.—Typical findings in eventration with displacement of the heart to the right. This patient had an associated parasternal defect also.

pain of peptic ulcer. This pain is sometimes characteristically relieved by the patient lying on the right side. The explanation for this is readily seen from the barium studies. The only constant physical findings were audible bowel sounds in the left chest and displacement of the heart into the right hemithorax, so-called dextrocardia (Fig. 2). These findings are not confined to eventration and the diagnosis ultimately depends upon fluoroscopic and barium studies.

Radiographic Findings.—Conspicuous elevation of the diaphragm which presents a smooth unbroken curve is said to be one of the cardinal diagnostic features of complete eventration. If the defect is localized, a cystic shadow may be reported.

In all cases screened (one third of the series), the diaphragm was mobile, though often limited in its range of movement. The final movement was always downward on sniffing and the eventration itself presented a dicroticlike pattern. The reason for this is obvious for, as the peripheral muscular ring contracts, the lax eventrated portion does not take up quickly and in some cases might move initially in a paradoxical manner. There is some delay before the muscle takes up the lax membranous portion, which due to the rising positive intraabdominal pressure and negative intrapleural pressure, travels up, but this is checked as the normal peripheral muscle takes up the slack. Its final movement therefore is always downward. This concurs with Evans and Simpson (1950), and Bisgard (1937).

This point is borne out; a patient whose history and x-rays were suggestive of eventration, but whose whole diaphragm was markedly paradoxical through all stages on screening. Because of troublesome gastric symptoms a surgical repair was carried out and it was seen that the phrenic nerve was atrophic. The diaphragm failed to contract after faradic stimulation of the nerve and examination of the diaphragm itself showed that all the normal components were present but the muscular portion was atrophic. This case would fall into the group of so-called acquired eventrations.

Barium meal and enema are frequently diagnostic as they may demonstrate the stomach rolled upside down with the splenic flexure alongside lying beneath the intact dome of the diaphragm. There is no reflux of barium up the esophagus in the Trendelenburg position. In our patients, the stomach emptied rapidly with the patient lying on the right side, which explains the relief from pain obtained by this maneuver. In all patients the stomach appeared larger than normal and this could be conducive to hemorrhage and volvulus. The only condition with which eventration of the diaphragm could be confused is a hernia through the dome of the diaphragm. Screening and radiography will often fail to differentiate the two. This sort of defect on screening will give a similar pattern to that found in eventration (Figs. 3 and 4).

Treatment.—In the past it has been stated that there is no place for surgical treatment. In the majority of cases, treatment is unnecessary but in those people who have symptoms surgery should be undertaken. We also advise correction in young patients with a gross abnormality because a physiologic operation can easily be performed and the fault corrected.

If the defect is localized, there is no problem. This merely means resection of the membrane and suturing of the muscular components, care always being taken not to jeopardize the lateral division of the phrenic nerve. When the whole dome is involved, surgical repair at first may appear formidable, but complete mobilization of the muscular component can be carried out, and after resection of the defective portion, muscle-to-muscle suture performed. A careful dissection around the chest wall and the pericardium is imperative, mobilizing the muscular portion of the diaphragm to its fullest extent. This muscular portion is often well hidden and appears almost to be covered by its own membrane. Once it is fully mobilized, the affected portion of the diaphragm

Fig. 3.

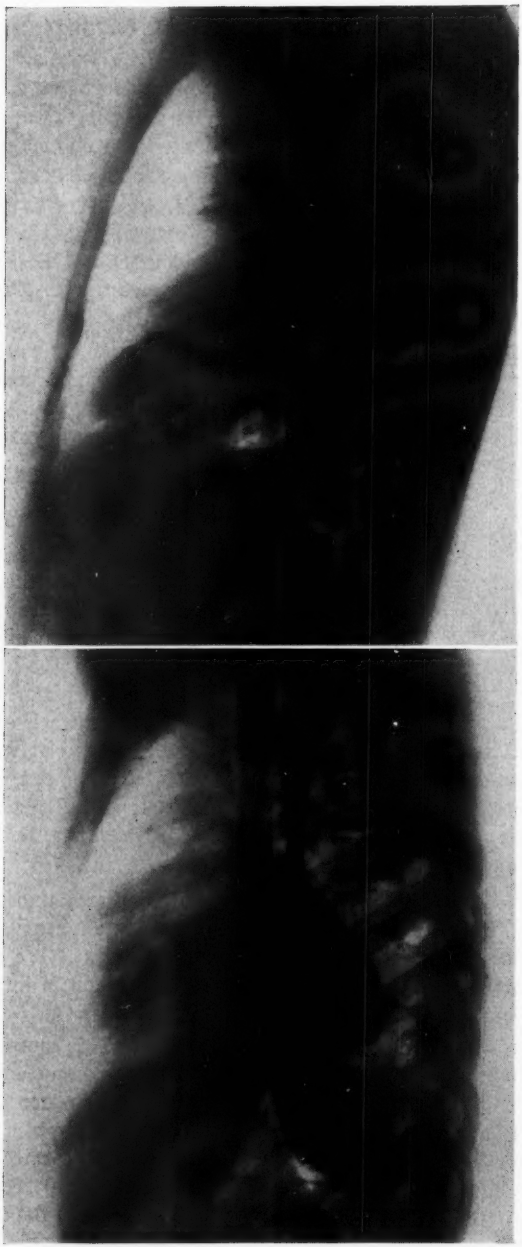
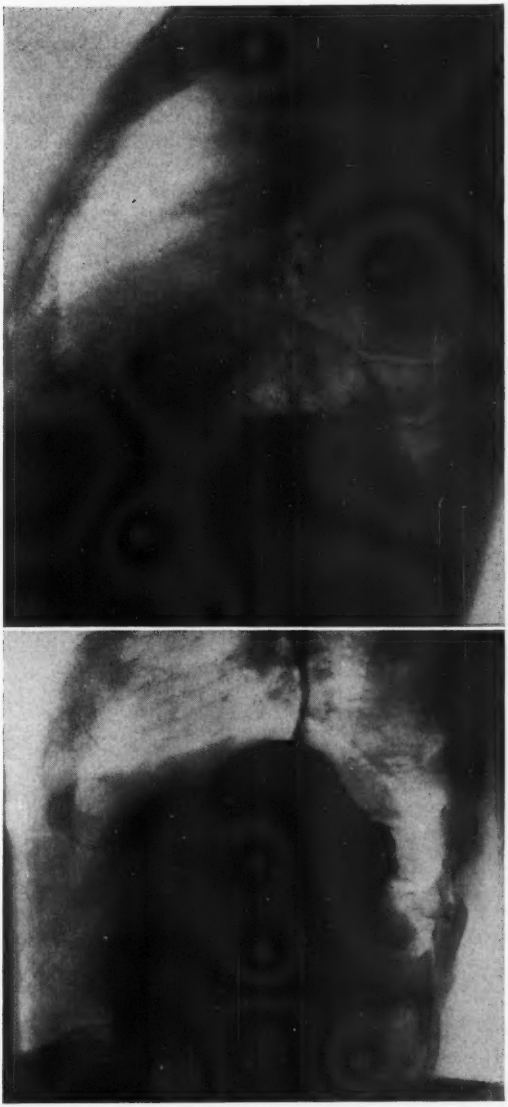


Fig. 4.

Figs. 3 and 4.—These x-rays show a lateral view and barium studies of a case of hernia through the dome of the diaphragm. It is extremely difficult to tell this from an eventration, preoperatively.

A.



B.

Fig. 5.—Case 1. *A* and *B*, Lateral films with excessive resting gastric contents. The barium studies show the rotation of the stomach upward. Following repair, barium studies showed the stomach lying normally.

can be resected and muscle-to-muscle suture performed. In none of these cases was it difficult to obtain muscular apposition, and postoperative screening showed an intact diaphragm with limited but normal movement on respiration. No reinforcement such as tantalum mesh or fascia lata grafts is necessary.

CASE REPORTS

CASE 1.—The patient, a man aged 43 years, whose symptoms began at the age of 31. He complained then of acute indigestion with pain radiating to the back. This acute epigastric pain persisted and was not particularly related to food. It was never relieved by medicines and after a meal there was troublesome flatulence. He always had a sensation of fullness in the stomach and this was aggravated if he sat up very long. When first seen his symptoms had progressed and the only way he could get relief was by lying down in bed. There was no history of dyspnea on exertion. The membranous portion of the diaphragm was resected, the peripheral muscle mass mobilized extensively and muscle-to-muscle suture performed. Since the operation he is free of symptoms. Postoperative barium studies show that the stomach is lying normally and the diaphragm moves down on inspiration (Fig. 5, *A* and *B*, and *C*).

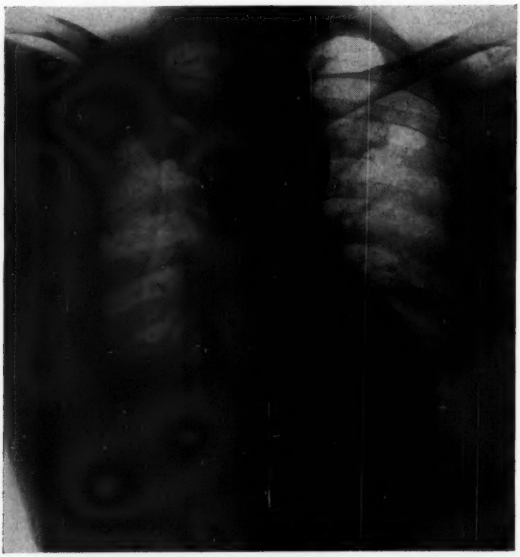


Fig. 5.—*Cont'd.* *C*, Posteroanterior film showing the diaphragm lower on the left side than on the right.

CASE 2.—The patient was a man, aged 67 years. One year prior to operation he had a melena of such severity that a tranfusion of 4 pints of blood was required. He was otherwise symptom free at the time. Barium studies then showed an eventration with typical rotation of the stomach and no evidence of gastric or duodenal ulceration. Three months later he developed sharp pains in the epigastrium and the right hypochondrium occurring one-half hour after meals. Lying on the right side relieved the pain. At this time he noticed dyspnea which progressed until, upon admission, it was so severe that he could not walk and talk at the same time. He had epigastric pain, flatulence, and a feeling of distention in the abdomen as if "blown up with wind." This was always relieved by lying on the right

A.

B.

Fig. 6.—Case 2. This patient had severe and repeated melena and gastrostaxis. *A* and *B*, Pre- and postoperative barium studies with typical rotation of the stomach upward. Following repair, the stomach lies and empties normally.

side. He had had several more small melena prior to admission and one while awaiting operation. In recent years he had been gaining weight and had put on nearly 28 pounds. Screening showed there was no true paradox and in the final phase of inspiration the site of the eventration moved downward. Thoracotomy revealed a localized eventration entirely surrounded by a muscular ring. The defect was excised and good apposition of muscle to muscle obtained. Since operation the symptoms have been completely relieved. Figs. 6*A* and 6*B* show pre- and postoperative barium studies.

CASE 3.—A boy, aged 13 years, had no symptoms but it was felt that such an extensive defect warranted repair (Fig. 2). At thoracotomy, there was an area of eventration about 5 inches in diameter surrounded by a good muscular rim. Medial to the muscular rim was a small parasternal defect which contained extraperitoneal fat. Apposition of muscle to muscle was simple and postoperative studies showed that the diaphragm moved normally.

The other cases in which operation was performed presented no technical difficulties and restoration of muscle to muscle was obtained. Postoperative screening showed a mobile, intact diaphragm.

SUMMARY

Surgery of eventration of the diaphragm is discussed and while 32 cases were seen only 5 required surgery for symptoms.

It is felt that the use of foreign bodies is unnecessary in the repair of this defect, for with adequate mobilization of the muscular portion of the diaphragm, muscle-to-muscle suture can be performed after resection of the defective portion.

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MULTIPLE RIB FRACTURE WITH INSTABILITY OF CHEST WALL

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DURING the past fifteen years there has been a marked improvement in the mortality and morbidity rates of patients with multiple rib fractures. This change has been brought about largely as a result of a better understanding of respiratory physiology by the medical profession and the control of infections by the antibiotics. A thorough understanding of the mechanics of respiration, the alterations which take place following injury, and the correction or, preferably, prevention of these changes is more important than any surgical technique for fixation of fractured ribs. We should like to emphasize in particular the importance of (1) early relief of pneumothorax by insertion of a large intercostal catheter (No. 28 or 30 F., Foley), (2) temporary stabilization of an instable chest wall by external traction, (3) removal of blood from the pleural cavity when present in significant quantity, (4) replacement of blood volume to normal level, (5) nasotracheal suction every hour, which must stimulate cough to be effective, (6) tracheotomy if nasotracheal suction is not effective or practical, and (7) intercostal nerve block anesthesia if possible, however, many patients have extensive bilateral fractures or other complications which make this impractical at times.

After accomplishing the stabilization of the patient and ascertaining that there are no ruptured viscera or other injuries necessitating prior treatment, one should then consider permanent stabilization of the chest wall, if there is significant paradoxical motion of the chest wall, or if there is a considerable deformity of the chest due to the fractured ribs. Twenty-four hours is usually sufficient for evaluation and stabilization of the patient.

The treatment of multiple rib fractures with paradoxical motion or deformity of the chest has not kept pace with advances in other branches of thoracic surgery. There are three reasons for desiring an improved method for treating such injuries: (1) competent investigators[1, 2] have shown that a mortality rate of 10 to 20 per cent exists in patients having rib fractures associated with pleural or lung complications, (2) the long period of immobilization in bed with the traction technique, as advocated by Heroy and Eggleston,[3] has many associated complications, and (3) last, but not least, the economic factor of prolonged hospitalization and time lost from the patient's occupation demands a method of quicker rehabilitation of the patient. We shall describe in this report a method of treatment which we think is an improvement on existing methods and has worked satisfactorily in our hands.

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Blades and Kent,[4] in 1940, advocated the simple expedient of drilling holes in the ends of sectioned ribs and securing them with silk ligatures as a method of fixing ribs at points of division. Klassen,[5] in 1949, advocated medullary pegging with autogenous medullary rib pegs as a method of obtaining a pain-free stable thorax following thoracotomy. Coleman and Coleman,[6] in 1950, advocated a method of wire fixation of the rib fragments. Overholt and Kenny,[7] in 1952, devised a mortise and tenon fixation of divided ribs.

We have found that the stabilization of the flail chest can best be accomplished by the use of the intramedullary Rush nail. Wiring the fragments as advocated by Coleman and Coleman has been used where intramedullary fixation is not practical.

We have used both general and local anesthesia with equally good results. General anesthesia through an endotracheal tube has been the method used in most cases, and should be chosen if any intrathoracic work is likely. In a few patients we have used intercostal nerve block and local infiltration anesthesia where there was little or no pneumothorax or hemothorax. Although at least a small opening in the pleura is usually made during the procedure, the patient, with an intercostal tube in the pleural cavity which is attached to a water-seal bottle, can keep the lung expanded by coughing and blowing against the cheeks.

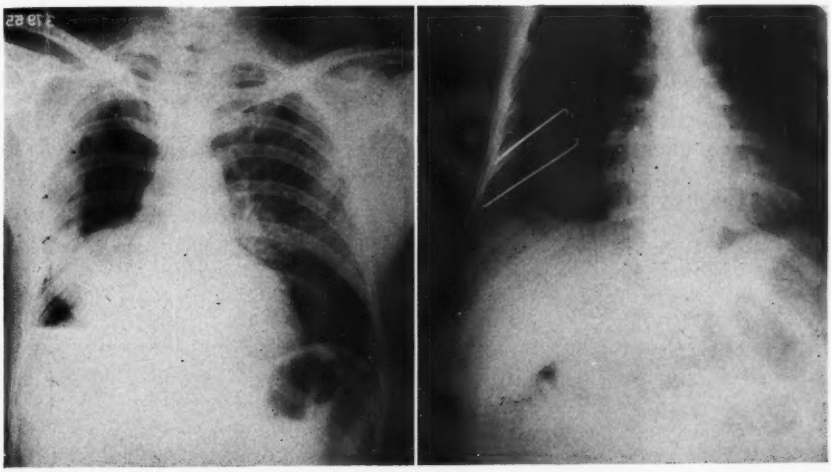
The technique employed is to use a generous incision parallel to the ribs and over the center of maximal deformity or maximal paradoxical motion. The fractured ribs are exposed and a drill hole is made approximately 3 to 4 cm. from the ends of the fragments. The smallest diameter intramedullary nail of the Rush type, 6 to 8 cm. long, is then inserted so that the bevel of the nail will follow the contour of the rib. Wire sutures may be used for some of the upper ribs which are not accessible through the incision. In our cases, three nails have been sufficient to give adequate stabilization of the chest, regardless of the number of ribs fractured. Often only two nails and sometimes only one nail, properly placed at the center of an area of paradoxical motion, will adequately stabilize the ribs. It is probably best if possible, however, to use two or three nails as one will sometimes become loosened by severe coughing.

The advantages of this procedure are: (1) it gives better stability than other methods previously advocated, (2) the amount of pain that the patient has is greatly diminished, (3) much better anatomical approximation of the rib fragments can be obtained by this method, (4) blood and air may be aspirated from the pleural space at the time of surgery, (5) the pleural space may be irrigated at the time of surgery, and (6) the patient can usually leave the hospital by the tenth to fifteenth postoperative day unless he has other injuries.

We do not feel that it is necessary to remove these nails, but if it is desirable, this may be accomplished at a later date under local anesthesia as an office procedure. A few of the nails have worked loose over a period of several months. The end of the nail can be felt through the soft tissue. Usually the only symptom produced is the fact that the head of the nail can be felt by the patient.

We have a total of 14 patients treated by some form of internal fixation. All of these have been traumatic fractures except one, which was an esophageal

resection where several ribs were divided for more adequate exposure. In 9 of these patients intramedullary Rush nails only were used. Two patients were treated with a combination of intramedullary nail and wire, while in 3 patients wire only was used as a method of fixation. There have been no deaths in this group of 14 patients.



A. *B.*

Fig. 1.—Case 1. *A*, Roentgenogram showing fractures of the right second through eighth ribs, with the lowest four showing double fractures and marked overriding of the posterior fractures. *B*, Postoperative roentgenogram showing expansion of the lung, and reduction with intramedullary nails of fractures of the seventh and eighth ribs.

CASE REPORTS

CASE 1.—O. C., a 46-year-old white man, was admitted to St. Joseph Hospital on Dec. 18, 1950. He had been cutting timber on December 13, when a tree fell on him. He was given emergency treatment at his local hospital.

Examination on admission showed a deformity of the right lateral chest wall with depression of the fourth through eighth ribs. The respiratory rate was 30. Breath sounds and voice sounds were absent over the entire right chest. Roentgenograms showed multiple fractures of ribs on the right, second through eighth, with the lowest four showing double fractures and marked overriding of the posterior fractures. There was a complete pneumothorax on the right with a small amount of fluid at the base.

On December 19, an intercostal catheter was inserted in the right second intercostal space and attached to a water-seal drainage bottle, with rapid expansion of the lung. On December 22, under general anesthesia, fractures of the right seventh and eighth ribs were reduced and immobilized with Rush intramedullary nails. Fracture of the sixth rib was stabilized with stainless steel wire through drill holes in the ends of the fragments. A moderate amount of bloody fluid was removed from the pleural cavity.

The postoperative course was complicated only by accumulation of pleural fluid, necessitating thoracenteses for removal. On one occasion, streptokinase was injected to liquefy clotted fluid. The patient was dismissed from the hospital on the fifteenth postoperative day (Fig. 1).

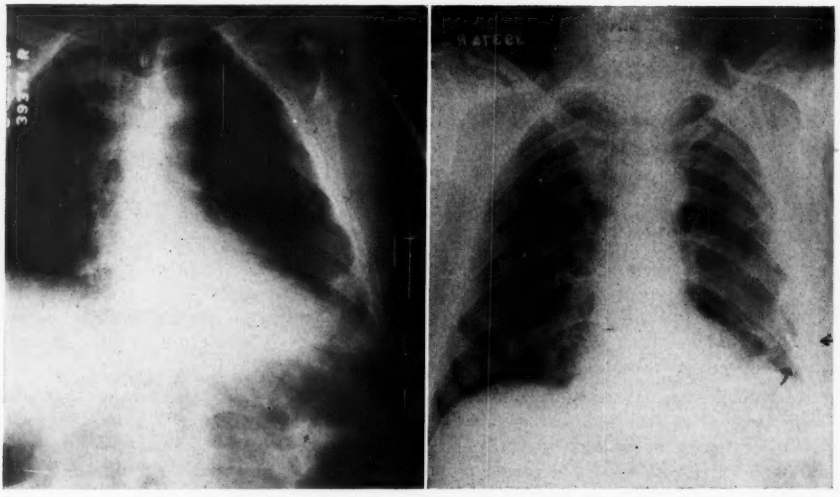
CASE 2.—A. P., a 55-year-old white man, was admitted to St. Joseph Hospital on March 27, 1951. He had been injured in an automobile accident twenty-four hours before admission. He had experienced severe pain in the left chest with difficulty in coughing and breathing since the accident. He was sent to the hospital under oxygen administration in the ambulance. He also gave a history of having had a heart attack five years previously, and subsequently had noted some exertional and nocturnal dyspnea.

Admission examination showed marked mobility of fractured ribs on the left. The patient would not cough because of severe pain. The pulse was 100 to 110. Chest x-ray showed fractures of the left fifth through eleventh ribs, with considerable displacement of the seventh through tenth ribs. There was also moderate amount of fluid in the pleural cavity.

The patient was treated with gastric suction for abdominal distention and sand bags to the injured chest, and was examined by a cardiologist who felt he could tolerate the anesthesia and surgery contemplated.

On March 28, under general anesthesia, the fractured seventh, eighth and ninth ribs were immobilized by Rush nails, and intercostal polyethylene tubes were inserted for postoperative intercostal anesthesia.

Postoperatively, the patient was much more comfortable and the chest wall was quite stable. The recovery was delayed however by development of pneumothorax necessitating the insertion of an intercostal catheter for expansion of the lung. He was dismissed from the hospital on the fifteenth postoperative day (Fig. 2).



A. *B.*

Fig. 2.—Case 2. *A*, Roentgenogram showing fractures of the left fifth through eleventh ribs, with considerable displacement of the seventh through tenth ribs. *B*, Postoperative roentgenogram showing reduction of the fractures by intramedullary nails in the seventh, eighth, and ninth ribs.

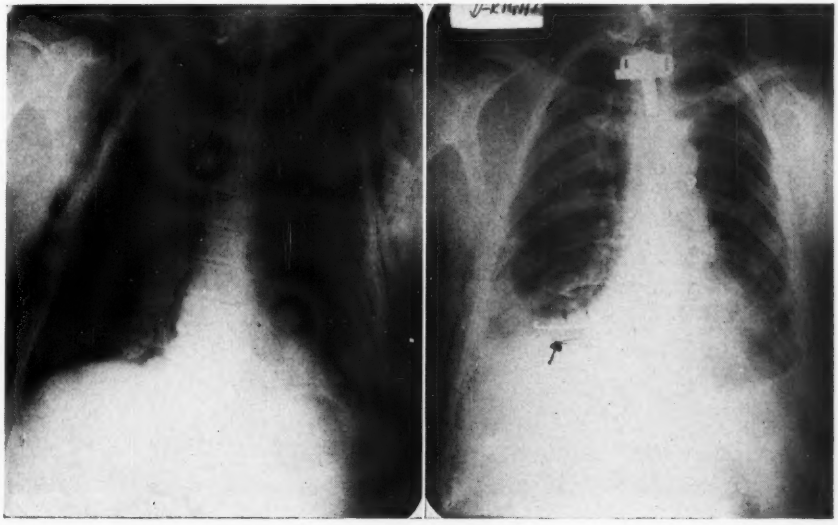
CASE 3.—E. B., a 50-year-old white man, was admitted to St. Joseph Hospital on June 2, 1952, a few hours after a tractor had turned over on him.

On admission, the patient was in marked respiratory distress with forced expirations and cyanosis in spite of oxygen administration. There was also an extensive wound of the right face. The blood pressure was 180/70, the pulse 140. There was an obvious deformity of the chest; the sternum was depressed below the medial end of the clavicle on the left, there was a complete separation of ribs from the sternum on the right side, and depressed

fracture of the upper anterior ribs on the right. Moderately severe subcutaneous emphysema could be seen and felt over the upper chest and neck. The breath sounds were indistinct and rhonchi were loud over both lower lungs.

Chest x-ray showed bilateral pneumothorax with almost complete collapse of both upper lobes, and marked subcutaneous emphysema of the chest and cervical region. There were fractures of the anterior right first and second ribs with moderate displacement of the first rib.

The patient was taken immediately to the operating room from the x-ray department, and an intercostal catheter was inserted in the anterior second space, right and left, and attached to a water-seal drainage bottle. Air was expressed under pressure from both pleural cavities when an opening was made for the catheter. There was immediate improvement in his breathing and color. A bilateral intercostal nerve block was then done with some relief of pain temporarily. The extensive face wound was débrided and closed under general anesthesia.



A. *B.*

Fig. 3.—Case 3. *A*, Roentgenogram showing bilateral pneumothorax with marked subcutaneous emphysema of the chest wall and cervical region. There are fractures of the anterior right first and second ribs, transverse fracture of the sternum at the second rib level, and fractures of the cartilages along the right sternal margin, with complete separation of the ribs from the sternum. *B*, Postoperative roentgenogram showing the lungs to be expanded. An intramedullary nail has been used in the fifth rib across the fractured cartilages into the sternum.

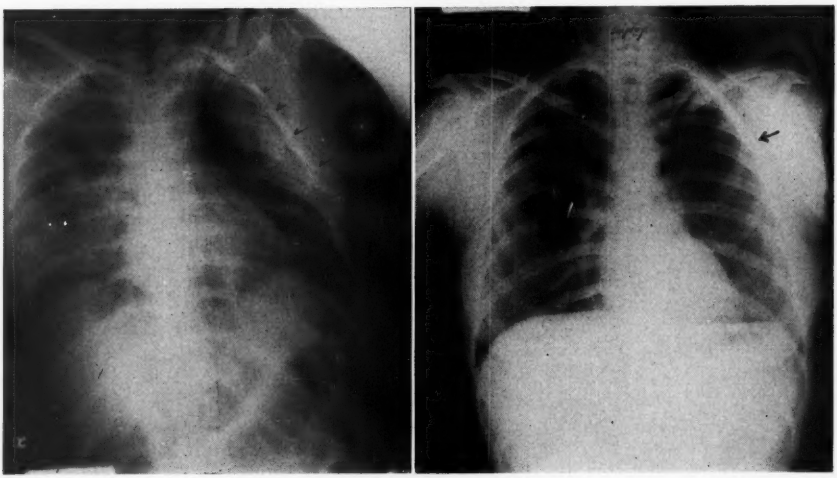
The patient continued to have considerable motion at the site of the costochondral fractures along the right sternal margin, and associated pain. On June 3, under local anesthesia, a Rush nail was inserted into the medullary canal of the right fifth rib across the fractured cartilage into the sternum. This stabilized the lower chest, but there was still considerable motion in the upper chest so another incision was made over the right second rib, anteriorly. The sternum was fractured transversely at this level, so would not hold a Rush nail; therefore, the fractures were immobilized with wire and silk sutures.

Postoperative Course.—After admission to the hospital, nasotracheal suction was done every hour. After forty-eight hours it was apparent that secretions were not being adequately evacuated from the tracheobronchial tree, so on June 4, a tracheotomy was done. The lungs remained expanded. There were moderate bronchopleural air leaks for several days but these

closed spontaneously. Thoracentesis was done on each side for removal of pleural fluid. The patient was dismissed from the hospital on the eleventh day after admission or the tenth day after stabilization of the chest wall (Fig. 3).

CASE 4.—H. S., a 32-year-old white woman, was admitted to St. Joseph Hospital on July 23, 1954, with history of being injured in an automobile accident three days previously. She had had marked difficulty in breathing and coughing following the injury.

Admission examination showed the patient to be in obvious respiratory distress. She was cyanotic propped up in bed in an oxygen tent. Respirations were rapid and labored with forced expirations. There was a moderate degree of paradoxical motion of the left lower chest wall. There was evidence of multiple fractures of the ribs on the left, and fracture of the left clavicle and right proximal humerus. Pneumothorax had been present on the left side initially, but had been corrected by insertion of an intercostal catheter by her referring physician. Chest x-ray showed multiple left rib fractures, second through ninth, fractured left clavicle and transverse fracture of the surgical neck of the right humerus.



A. *B.*

Fig. 4.—Case 4. *A*, Roentgenogram showing multiple rib fractures on the left side, second through ninth, and fracture of the left clavicle. *B*, Postoperative roentgenogram showing an intramedullary nail in the fifth rib. The third and sixth ribs are immobilized with stainless steel wire through drill holes in the ends of the fragments.

Shortly after admission of the patient to the hospital, under local anesthesia, the left seventh rib was grasped with a uterine tenaculum in the anterior axillary line and a 5-pound weight attached with rope and pulley. This stabilized the chest wall very well, diminishing the pain and improving the respiratory exchange. The lungs were quite wet, so bronchoscopy was done in bed under local anesthesia with removal of a large quantity of secretions with suction. The morning after admission the lungs were clear and the patient was breathing easily with external traction. On July 25, under intercostal nerve block and local infiltration anesthesia, the left fifth rib fracture was stabilized with an intramedullary Rush nail. Fractures of the left third and sixth ribs were immobilized with stainless steel wire through drill holes in the fragments.

Postoperatively, the chest wall remained stable and the patient had much less pain with coughing. There were no complications. The fractured clavicle and humerus were treated by an orthopedic surgeon. She was dismissed from the hospital on the ninth postoperative day (Fig. 4).

DISCUSSION

A nail or pin of the Rush type seems particularly applicable to multiple rib fractures as it restores the normal contour of the rib and gives good stability to the rib cage when applied to only a few ribs at the center of the deformity. The principle of immobilization of fractures by this method has been adequately described elsewhere.[8, 9]

Technical considerations.—(1) The incision must be adequate to allow the drill and nail to be inserted tangentially to the rib. (2) The smallest diameter Rush nail may be too large for very small individuals. We have not used the nails in any children, but have encountered this difficulty in a few small adult women. We have used wire sutures to approximate the fragments in these individuals. (3) In fractures at or near the posterior angle of the rib, it is necessary to bend the nail to approximate the contour of the rib; however, the nail should fit tightly and should maintain the normal contour of the rib.

SUMMARY

(1) The general management of the patient with multiple rib fractures with instability of the chest wall has been outlined.

(2) An operative method of permanent stabilization of the chest wall by intramedullary Rush nails is described.

(3) Fourteen patients have been treated by open reduction and fixation of fractured ribs. Nine of these have been treated with the Rush nails without other methods of fixation with satisfactory stabilization of the rib cage.

Dr. O. B. Murphy and Dr. W. K. Massie, Lexington, Kentucky, have given valuable suggestions regarding use of the Rush intramedullary nails.

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SUTURE MATERIAL AND TECHNIQUE FOR BRONCHIAL CLOSURE AND BRONCHIAL ANASTOMOSIS

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BRONCHIAL fistula is not at present a major problem after pulmonary resection. There is practically only one cause of a bronchial fistula, whatever technique for bronchial closure has been used, and that is infection. The decreased incidence of bronchial fistula is therefore due to the antimicrobic therapy. Only once have I observed a bronchial fistula due to a suture being tied so tightly that it cut through the bronchial wall. At reoperation two weeks after the first operation, no signs of infection were observed and healing was obtained by reamputation and suture. A bronchial fistula, at present, is a rare but severe complication. The incidence of suture granulomas is, however, so high that I have made an effort to avoid them.

The suture granulomas are especially harmful in two groups of patients: (1) After bronchial closure in cases of resection for pulmonary tuberculosis. The suture granulomas cause an irritating cough until the sutures are coughed up or are removed by bronchoscopy. The suture granulomas are often found to contain tuberculous tissue and give rise to a positive guinea pig test on sputum or the gastric washing. After removal of the suture granulomas, the guinea pig test will often turn negative. (2) In cases with bronchial anastomosis. Several suture granulomas along the suture line will obstruct the lumen and cause an atelectasis.

Stainless steel sutures were first used as suture material. In the presence of infection, however, bronchial fistulas did occur. The stainless steel sutures often caused tuberculous suture granulomas, and they were difficult to remove by bronchoscopy. We therefore abandoned the use of stainless steel sutures and favored silk sutures on Atraumatic needles. The incidence of suture granulomas did not diminish but the silk sutures were much easier to remove. In cases of bronchial and bronchotracheal anastomosis, the suture granulomas obstructed the lumen and most of the sutures had to be removed by bronchoscopy. Some sutures were coughed up.

In order to avoid suture granulomas, I am now using only chromic catgut on Atraumatic needles (Ethicon 30-day chromic catgut is used, although no difference was encountered with the 20-day chromic catgut). The bronchial fistulas have not increased and the suture granulomas have disappeared. Chromic catgut as suture material for the bronchus has already been used by

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Brunn in 1929 for one-stage lobectomy, by Shenstone and Janes in 1932 for the tourniquet lobectomy, and by Graham in 1933 in his historic, first successful one-stage pneumonectomy for carcinoma. The fistula that did develop was not due to the suture material but to the infection. Now we can avoid suture granulomas by going back to catgut as suture material for the bronchus.

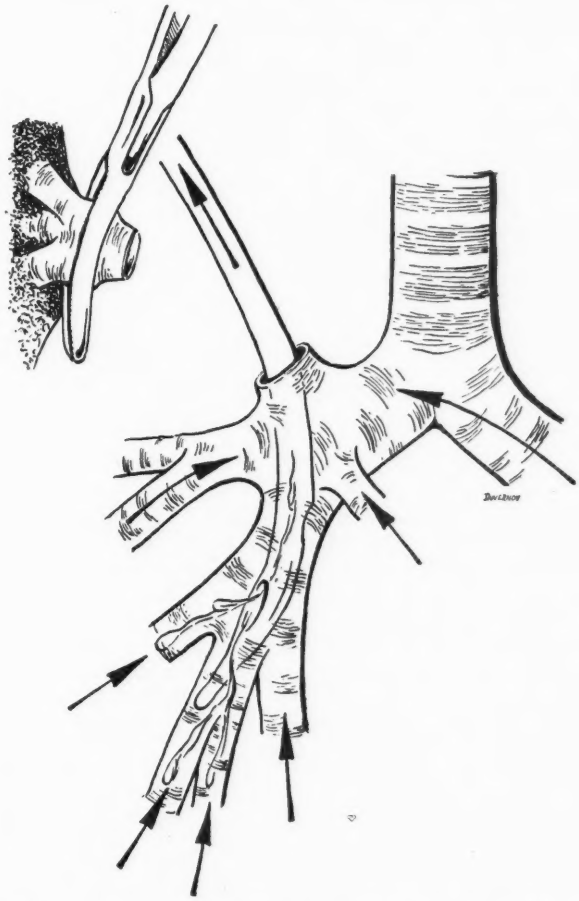

Fig. 1.—A clamp is placed on the bronchus peripheral to the division, but not on the central stump. The bronchial tree is aspirated before the bronchus is closed.

METHODS

I. Earlier we used the invagination technique for bronchial closure described by Crafoord. Excellent results were obtained by this method even before the introduction of antimicrobic therapy. The invagination is easy to perform on a soft bronchus, especially after a pneumonectomy. A pedicled pleural flap was sutured over the bronchus.

II. Isolated stainless steel sutures and later silk sutures were used for bronchial closure in a group of cases for comparison with the invagination technique. A pedicled pleural flap was sutured around the bronchus.

III and IV. Catgut sutures on Atraumatic needles were used as the suture material. In Group III, fine Deknatel silk sutures were placed between the

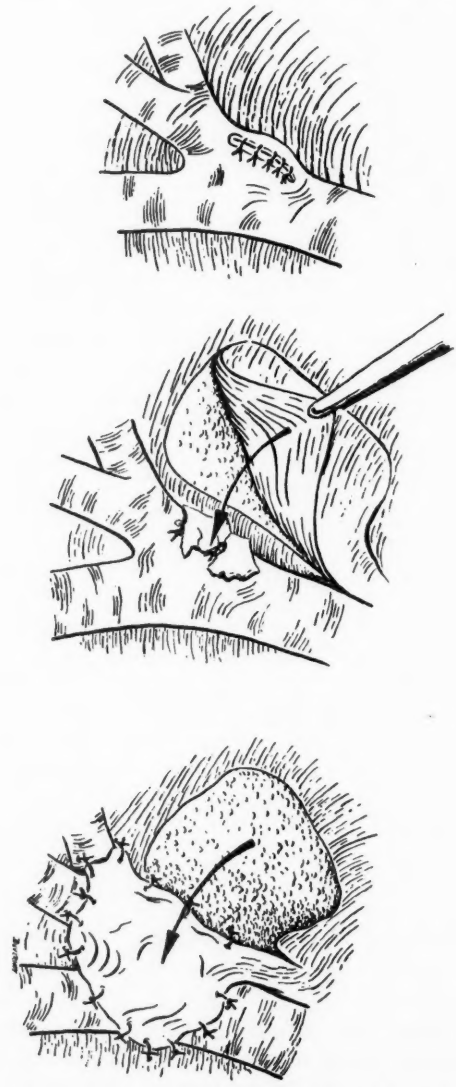

Fig. 2.—The bronchus is closed with one row of isolated terminal catgut sutures. Streptomycin crystals are placed under a pedicled pleural flap sutured around the bronchial stump.

catgut sutures, care being taken to place the silk sutures extramucosal when possible. In Group IV, only catgut sutures were used. The bronchial stump was always covered with a pedicled pleural flap. The present technique for bronchial closure is as follows:

1. In order to avoid trauma to the bronchial stump, a central clamp is never used and the bronchus is treated open. Any accumulated secretion is sucked out first. The prone position is used in cases with tuberculosis, see Fig. 1.

2. To avoid suture granulomas, catgut on Atraumatic needles is used. For a segmental bronchus, No. 4-0 or 3-0 catgut is used, for a lobar bronchus No. 3-0, and for a pneumonectomy No. 3-0, or 2-0 is used. One row of isolated terminal sutures is used. They should not be tied too tightly or they may cut through.

3. In order to diminish the danger of infection with bronchial fistula, a high local concentration of streptomycin is obtained by placing streptomycin crystals under the pedicled pleural flap which is sutured on the bronchus, see Fig. 2.

RESULTS

In order to evaluate the different techniques for bronchial closure only cases of pneumonectomies and lobectomies for pulmonary tuberculosis have been analyzed. The incidence of fistulas in cases of segmental resection is higher, but these fistulas are often due to leakage from the resection area. As it may be difficult to prove if a fistula is localized in the segmental bronchus or in the resection area, cases with segmental resection are excluded from this analysis.

Pneumonectomies.—The findings from 146 pneumonectomies are shown in Table I. There are altogether 3 cases of bronchial fistula (2.1 per cent), 2 were caused by a tuberculous infection, the third was secondary to a staphylococcal empyema. The 2 cases with tuberculous infection were reoperated upon, the bronchus closed with stainless steel sutures, and the thoracoplasty enlarged. In both cases, the bronchus reopened after a few days and the patients died later on. Invagination will not prevent a bronchial fistula in the presence of infection.

TABLE I. THE COMPLICATIONS OF BRONCHIAL CLOSURE AFTER PNEUMONECTOMIES FOR PULMONARY TUBERCULOSIS

TECHNIQUE OF BRONCHIAL CLOSURE	TOTAL NUMBER OF CASES	BRONCHIAL FISTULA	SUTURE GRANULOMA
I. Invagination	65	1	4
II. Isolated silk or stainless steel sutures	42	1	8
III. Catgut + silk	18 } 39	0	0
IV. Catgut	21 }	1	0
TOTAL	146	3	12

Twelve of the 107 cases in which the bronchus was closed with silk or stainless steel sutures had to have the sutures removed from the bronchial stump by bronchoscopy. One of these patients had to have 5 bronchoscopies performed for removal of sutures causing granulomas. (This incidence of suture granuloma may be too low as only patients with a long-standing irritating cough were bronchoscoped.)

Five patients reported that they coughed up sutures. Naturally, more patients have coughed up sutures without noticing or reporting it. No suture granulomas have been found in the cases with the bronchus closed with catgut.

Lobectomies.—The findings in 230 cases of lobectomy for pulmonary tuberculosis are summarized in Table II. The invagination technique was used

TABLE II. THE COMPLICATIONS OF BRONCHIAL CLOSURE AFTER LOBECTOMIES FOR PULMONARY TUBERCULOSIS

TECHNIQUE OF BRONCHIAL CLOSURE	TOTAL NUMBER OF CASES	BRONCHIAL FISTULA	SUTURE GRANULOMA
I. Invagination	4	0	0
II. Isolated silk or stainless steel sutures	113	3	17
III. Catgut + silk	55 } 113	0	0
IV. Catgut	58 }	0	0
TOTAL	230	3	17

in only 4 cases. There is a danger in invaginating the bronchus too much of obstructing the proximal bronchus. As nothing is to be gained by the invagination technique, the simple closure described is preferred.

Fistula: There were 3 cases complicated with bronchial fistula, 1 due to a tuberculous infection, 1 followed an infection with *Staphylococcus aureus* in a plastic plomb placed extrapleurally after the lobectomy. The third bronchial fistula followed a lobectomy in which a staphylococcal empyema was opened during operation. All 3 cases were reoperated on, the bronchus closed with stainless steel sutures or silk but the bronchus reopened in all 3 cases after a few days. Two patients died, 1 (with the infected plomb) survived after a wide excision of the chest wall (Schede thoracoplasty).

Sutures had to be removed in 17 of 117 cases having the bronchus closed with nonabsorbable suture material. This incidence of suture granuloma may be too low as only patients with an irritating cough were bronchoscoped. The suture granuloma may contain tuberculous tissue and be a serious complication. In one case a reoperation was necessary (see Case 1).

CASE REPORT

CASE 1. A 28-year-old woman had the basal segments of the right lower lobe removed in 1950 for a tuberculous cavity. The bronchus was closed by four isolated stainless steel sutures and one running suture of fine linen. The stump was covered by a pedicled pleural flap. During the following four years, the patient had eight bronchoscopies performed for treatment of tuberculous suture granulomas. All of the stainless steel sutures could not be removed through the bronchoscope. In 1953, the patient developed a tuberculous cavity in the remaining superior segment of the right lower lobe. In June, 1954, a resection of this superior segment right lower lobe was performed as well as a reamputation of the

lower lobe bronchus above the old suture line. Inspection of this suture line showed a stainless steel suture in the center of necrotic mucosa. The stainless steel suture was surrounded by granulation tissue which proved to be tuberculous at the microscopic investigation.

There were 7 cases with bronchotracheal or bronchial anastomosis. In 3 cases, the anastomosis was performed with silk sutures. All 3 patients had to have the sutures removed by bronchoscopy. Suture granulomas around the suture line caused partial obstruction and 1 patient had to have six bronchoscopies performed for removal of all silk sutures before healing was obtained. In 4 cases, the bronchial or bronchotracheal anastomosis was performed with chromic catgut sutures. Bronchoscopic control after one to two months revealed smooth healing of the suture line with no suture granulomas.

SUMMARY

Bronchial fistula is a rare complication practically always due to infection. The incidence of bronchial fistula does not increase if catgut is used as suture material.

The use of nonabsorbable suture material has caused suture granulomas in a significant number of cases. In cases of bronchial or bronchotracheal anastomosis, the suture granulomas may obstruct the lumen. In cases of resection for pulmonary tuberculosis, tuberculous granulations may be found around the suture. The use of catgut will prevent the formation of suture granulomas.

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INTRACARDIAC ANGIOGRAPHY: CONTROLLED INSTANTANEOUS INTRA-ATRIAL RELEASE OF CONTRAST MATERIAL IN MAN

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SINCE the demonstration of the practical applications of angiocardiography by Robb and Steinberg in 1938,[1] numerous modifications have been set forth. However, little alteration of their basic method has occurred. Technical advances have followed two courses: (1) improving the technique and increasing the frequency of serial radiography, and (2) achieving adequate concentration and localization of contrast substances.

1. Biplanar exposures at a rate of ten to twelve per second[2] and cinefluorography[3] provide excellent serial visualization of the flow of contrast material through the heart and great vessels. Unfortunately, this requires complex expensive equipment. Generally, rapid cassette changers,[4] or roll film magazines[5] are adequate for most clinical work. As a matter of fact, single or timed multiple exposures with existing x-ray equipment may prove satisfactory, although such techniques are probably no longer justified.

2. Adequate concentration of the contrast material to permit visualization can be produced only by very rapid injection of the viscous, highly concentrated contrast substance into a suitable vein.[1] To prevent dilution of the dye as it enters via the systemic veins into the heart, large-bore intracardiac catheters have been inserted via the external jugular vein.[4] "Selective" angiograms can be obtained by means of a No. 9 cardiac catheter with the contrast material injected under great pressure.[7] Direct heart puncture allows injection of the contrast substance into one of the ventricles[8] or into the left auricle.[9] Artificial reduction of intrathoracic circulation as an aid in angiocardiography has recently been proposed.[10]

In our experience, adequate angiocardiographic visualization can be obtained in most children using the standard technique of injection of the contrast material (usually 70 per cent Diodrast) into a suitable arm vein. The roll film magazine provides exposures at one-half to one second intervals. However, satisfactory visualization in adults is limited by the rapid dilution of the injected substance. Rapid intravenous injection of 70 per cent Diodrast in volumes of 40 to 50 c.c. is hard to achieve. Particularly in patients with

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cardiac enlargement, adult angiocardiograms have been of poor quality. Obviously, a more nearly ideal method requires the liberation of a bolus of concentrated contrast material within the heart.

Because of obvious difficulties and dangers associated with such procedures as direct cardiac puncture, various other possibilities have been explored in this laboratory. This communication is a preliminary report of our early experience with a method which provides controlled instantaneous release of large volumes of contrast material within the right atrium. This method has proved to be safe and practical for most clinical applications.

DEVELOPMENT OF TECHNIQUE

A special balloon-tipped catheter had been used to produce unilateral pulmonary artery occlusion[11] in more than 60 patients undergoing hemodynamic studies. No significant untoward effects had occurred. Despite the rather complex structure of the catheter, thrombo-embolic complications have been of no consequence. In the course of five of these studies, inflation with 8 to 20 c.c. of 15 per cent Diodrast inadvertently caused rupture of the rubber cuff, with sudden liberation of the contrast material as seen by fluoroscopy. In no case was this rupture attended by any subjective symptoms. The obvious application of this observation to angiography then presented itself.

Various methods for sudden liberation of the contained contrast material from the balloon were explored. When a rubber balloon was tied over the end of a cardiac catheter, overinflation, of course, produced rupture; but prediction of the volume necessary or time of rupture was impossible. Also, the danger of fragmentation of the rubber with embolization appeared prohibitive. Methods for release of the balloon by slipknots, weakened seams, and electrocautery were also attempted and ultimately rejected. Finally, a model was constructed which in preliminary studies appears satisfactory.

METHOD

At this writing, continuous modification of the special catheter is under way. Following each study, the construction of the catheter has been altered. Fig. 1 shows an over-all view of the catheter, with a close-up of the tip, of the parent model, which was constructed from a standard double lumen cardiac catheter. Details are given in the legend for Fig. 1.

This technique has been applied only in adults or large children. The procedure is carried out as in ordinary cardiac catheterization, in the fasting state, under mild sedation (0.1 Gm. secobarbital). Under local anesthesia a large median vein in either arm is isolated and, with the balloon completely deflated, the tip of the catheter inserted. Heparin, 25 to 50 mg., may be given to prevent possible fibrin deposition. Under fluoroscopic and electrocardiographic control, the catheter is advanced until the tip has passed into the right atrium and just into the inferior vena cava. A small volume of contrast material (5 to 10 c.c.) is then injected to observe the position of the balloon, which should be in mid-atrium. The patient is then positioned before the x-ray unit and the desired amount of contrast material (40 to 50 cm. of 70 per

cent Diodrast) is injected as rapidly as possible (usually in 60 seconds). One second after x-ray exposures at one-half to one second intervals are begun, a sudden pull is exerted on the wire. This pulls down the cuff holding the proximal end of the balloon, resulting in sudden liberation of the contained solution. The catheter is withdrawn as soon as the exposures are completed.

RESULTS

Satisfactory x-ray visualization has been obtained in the first 5 patients studied. The illustration herein presented is from the fifth patient studied and represents the best result so far achieved. This patient was an eighteen-year-old

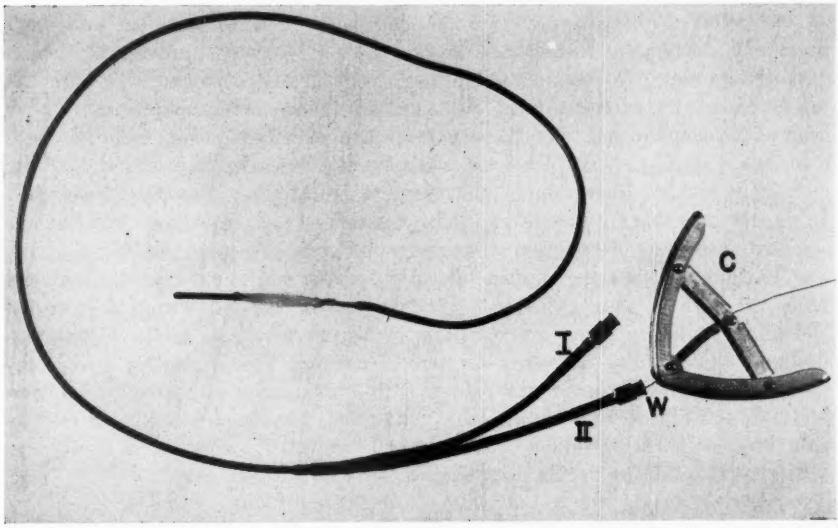

Fig. 1*A*.—Balloon-tipped catheter for controlled instantaneous release of contrast material in right atrium. The upper fitting, *I*, is for injection of contrast material via that lumen into the balloon at the tip. From the lower fitting, *II*, emerges a fine stainless steel wire, *W*, extending down this lumen. Pressure on the spring clamp, *C*, causes the wire to pull down the cuff which had secured the proximal end of the balloon.

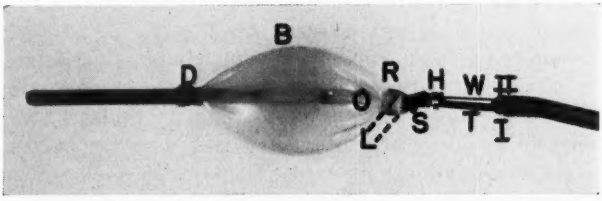

Fig. 1*B*.—Close-up of tip of catheter, actual size. *B*, latex balloon securely held by tight rubber cuff, *R*. Balloon is inflated via lumen *I* through hollow stainless steel tubing, *T*, ending in single-lumen catheter which is blocked off at its tip; an opening at its side, at *O*, inflates the balloon. Two fine silk ligatures, *L*, tied proximal to a shoulder, *S*, on *T* are drawn under cuff, *R*, and then back over to be tied to the end of the wire, *W*, which runs parallel to *T*, and ends in a ring, *H*, just proximal to shoulder, *S*.

After the balloon is inflated by the desired volume, sudden tension on the wire pulls down the two silk ligatures causing cuff, *R*, to roll back off the proximal end of the balloon, so that the contained material is suddenly liberated.

female with severe limitation from infancy, due to congenital heart disease. A clinical diagnosis of pulmonic stenosis was made. At cardiac catheterization, a classical pulmonary artery–right ventricular pressure gradient of severe pulmonic stenosis was demonstrated (Fig. 2). The abrupt transition from the low pulmonary artery pressure to the very high right ventricular pressure established the fact that the stenosis was valvular (rather than infundibular).

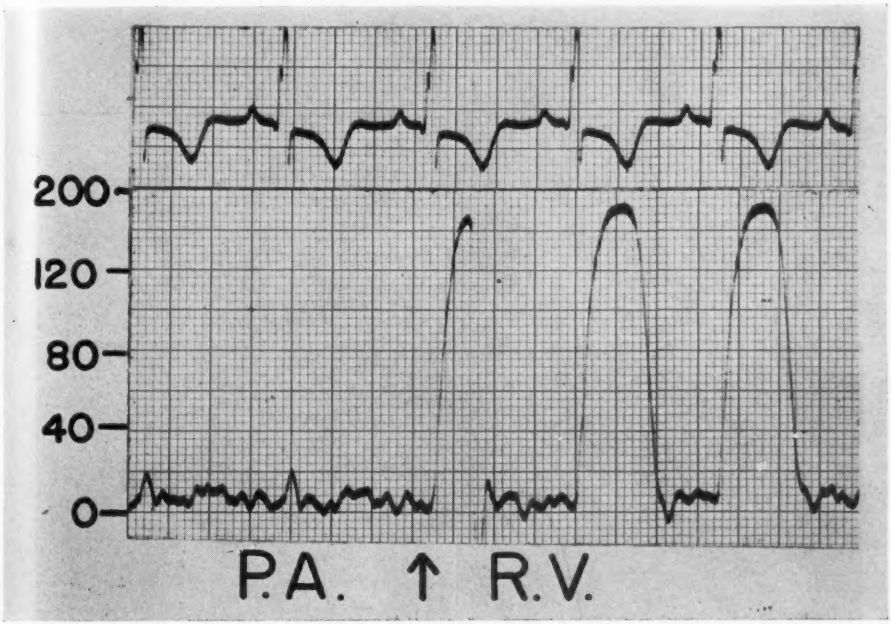

Fig. 2.—Isolated valvular pulmonic stenosis. Pressure tracings as catheter tip was slowly withdrawn from pulmonary artery (PA) to right ventricle (RV) show abrupt transition at the pulmonic valve (arrow) from low to very high pressure. (Electrocardiogram, Lead II, recorded simultaneously.)

The illustrations in Fig. 3 were selected from a series obtained during intracardiac angiography performed on this patient using the previously described technique. Fig. 3, *A* shows the inflated balloon in place in the right atrium just before release of the contrast material. In Fig. 3, *B*, one-half second after release, excellent visualization of the right ventricle is obtained. Fig. 3, *C* and *D* demonstrate the pulmonic valve during diastole and systole. The valve appears to be displaced somewhat upward and the outflow tract of the right ventricle appears narrowed.

Operation was performed by Dr. Claude S. Beck. The diagnosis and the position of the stenotic valve were confirmed; the very thick-walled outflow tract of the right ventricle was demonstrated. Section of the valve was followed by an excellent pressure response. Significant clinical improvement has resulted.

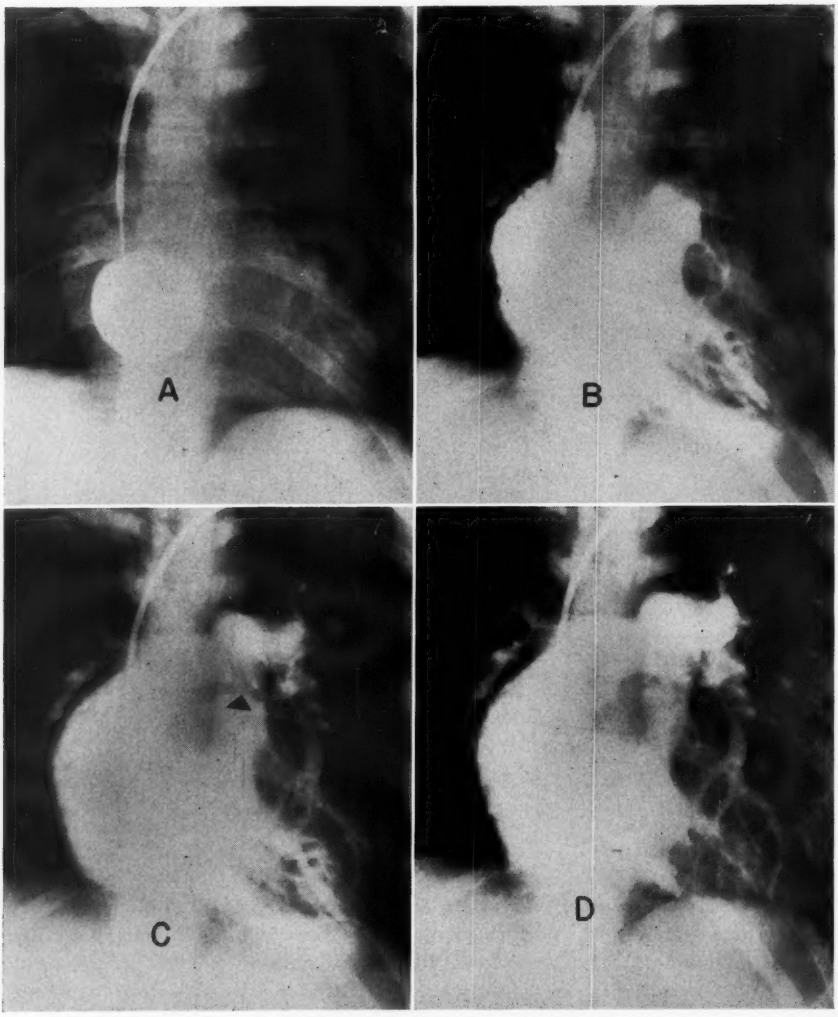

Fig. 3.—Intracardiac angiography by controlled instantaneous release of 40 c.c. of 70 per cent Diodrast in right atrium. Eighteen-year-old girl with isolated valvular pulmonic stenosis. Anteroposterior projection.

A, Balloon inflated with 40 c.c. of Diodrast in right atrium, just before relase.

B, One-half second after release. Note reflux up superior vena cava. The internal architecture of the right ventricle is well shown. The dye is just about to enter the pulmonary artery.

C, One-half second later, during diastole. Arrow is just at pulmonic valve. Architecture of valve demonstrated, and tiny "string sign" of dye.

D, One-half second later, during systole. Outflow tract of right ventricle narrower than *C* with larger opening in pulmonic valve.

Similar intracardiac angiograms have been performed in patients with the following: Ebstein's disease, tricuspid stenosis (postoperative), atrial septal defect, and mitral insufficiency.

COMMENT

In view of the inherent danger of occlusion of one or more of the orifices of the right atrium, it was considered advisable to carry out the first studies in patients with enlarged right atria. However, since inflation of the balloon and release can be carried out within one minute, any possible ball-valve effect can only be temporary.

In the first 5 patients in whom the complete procedure was carried out, the over-all reaction to sudden liberation of the dye appeared less severe than is usually observed with standard injection. Presumably, although a higher instantaneous concentration of dye perfuses the cerebral and coronary vessels, its rapid dispersal would make it less dangerous than perfusion of the vessel with a somewhat lower concentration but for a relatively much longer period of time.

Although fibrin particles are occasionally found on the catheter after removal, in the absence of a significant right-to-left shunt this appears to be of no consequence.

It appears that this method of instantaneous release of contrast material in the right atrium allows for more accurate timing of flow through the various cardiac chambers. Furthermore, the presence of a more concentrated "bolus" gives a higher concentration of contrast material for a longer period of time. The undesirable factor of continued flow into the right atrium from the superior vena cava is obviated. Superimposition of contrast material in various chambers is reduced.

Since the substance within the balloon is relatively noncompressible, sudden release does not greatly alter intracardiac flow pressure relationships such as would occur with introduction of the material under great pressure via an intracardiac needle or catheter.

General anesthesia, as required for most of the other special methods, has not been necessary, so that maximum patient cooperation can be obtained. Positioning of the patient is particularly easy, more so even than for ordinary angiocardiography. Once the catheter position is secured, the patient's arm need not be held elevated to obtain rapid injection of the dye. Injection into the catheter can be done in any comfortable position.

Where no special serial radiography apparatus is available, this method permits more accurate timing of the selected exposures. Unfortunately, however, repeat studies can only be done following removal of the catheter, reassembly of the balloon and release mechanism, and reinsertion of the catheter.

Since none of the highly concentrated contrast material comes into contact with the systemic vein used for insertion of the catheter, there is less likelihood of severe thrombophlebitis, although the catheter itself is somewhat irritating. There is no evidence that the sudden liberation of the material inside the heart produces endocardial irritation.

Further studies are now being performed. Simultaneous recordings of intracardiac pressures, arterial pressure, and electrocardiogram are being carried out during inflation and release of the balloon. An apparatus has been designed to correlate release and x-ray exposures with phases of the cardiac cycle.

SUMMARY

By means of a specially designed balloon-tipped cardiac catheter, a large volume of contrast material may be released instantaneously in the right atrium. This appears to be a safe and effective method for achieving adequate visualization for angiocardiographic purposes.

In the first 5 patients studied, the rapid liberation of the material produced no untoward effects. Studies in a patient with congenital pulmonic stenosis are presented. Excellent visualization of the right ventricle and stenotic pulmonic valve are demonstrated.

Further studies are now being conducted to determine the hemodynamic and electrocardiographic effects of this procedure and also to develop a catheter suitable for mass production.

I wish to acknowledge the technical assistance of the following: Bernard L. Charms, M.D., John Elder, M.D., Melvyn Reydman, M.D., Robert Newman, M.D., Mary Ellen Beck, Howard Siegel, Mary Rizika, Delores Fader, and Lou Vacha—all of whom contributed to the development of the method.

ADDENDUM

Since this report was submitted, a single lumen catheter with a simplified release mechanism has been devised, allowing more rapid injection and release of contrast material. More than 25 studies have been carried out, particularly in patients with rheumatic heart disease being considered for operation. Excellent results have been achieved (to be reported subsequently) without untoward effects.

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MELANOCARCINOMA OF THE ESOPHAGUS

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CHAPEL HILL, N. C.

INTRODUCTION

SINCE Baur's first reported case of malignant melanoma of the esophagus in 1906,[1] a total of 15 have appeared in the world literature.[2-16] The seventeenth case, which is described below, prompted us to review the available material in an attempt to resolve it into a concrete clinical and pathologic picture that might aid in the future diagnosis and treatment.

CASE REPORT

F. M., a 61-year-old Negro woman, was first admitted to the North Carolina Memorial Hospital on July 15, 1954, with the chief complaint of "difficulty in swallowing" solid food of about four months' duration. She experienced the sensation of food "getting stuck down deep" accompanied by mild epigastric burning and interscapular pain. Liquids in small quantities passed freely, and there was no history of cough, vomiting, sialorrhea, or hoarseness. She had lost about 20 pounds since the onset of her illness. Her general health had always been excellent, and the review of systems was noncontributory.

At the time of physical examination, the patient appeared as a well-developed, moderately well-nourished, elderly Negro woman in no acute distress. The temperature was 99° F., blood pressure 130/80, and pulse 80. A critical examination of each of the systems was essentially negative.

Routine laboratory studies that included a complete blood count, urinalysis, blood urea nitrogen, carbon dioxide capacity, serum chlorides, sodium and potassium, total proteins, and albumin were all within normal limits. An electrocardiogram was not remarkable.

A barium swallow outlined the esophagus in its entirety. An irregular, lobulated filling defect was described at the junction of the middle and distal thirds (Figs. 1 and 2). The radiologic impression was fungating carcinoma of the esophagus.

On the second hospital day, a bronchoscopy and an esophagoscopy were performed. The bronchoscopy revealed no abnormalities, but a large, polypoid, dark-bluish mass was encountered in the esophagus at the level described by the radiologist. A biopsy was taken. The histologic sections revealed a normal mucosa, submucosal infiltration by pleomorphic, anaplastic-appearing cells containing varying-sized, brownish-pigmented granules that were nonreactive to iron stains. The pathologic diagnosis was malignant melanoma. The skin, eyes, anus, rectum, and genitalia were carefully re-examined for a possible primary site, but none was found. Urinalysis for melanin was negative.

On the fifth hospital day, an esophagectomy, esophagogastrostomy, and pyloroplasty were carried out through a left thoracotomy incision. The esophagus was not fixed to the adjacent mediastinal structures. Abdominal exploration revealed no gross liver metastases, but pigmented lymph nodes were found near the celiac axis and along the distal third of the esophagus. The patient tolerated the procedure well.

Pathologic examination of the surgical specimen revealed a 14 cm. segment of esophagus with regional lymph nodes attached (Fig. 3). Five centimeters from the proximal end was a

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single, deeply pigmented, firm, pedunculated tumor mass measuring 4 by 2.5 by 1 cm. Its pedicle was broad, measuring approximately 2 cm. across and 1 cm. in length. The surface of the lesion was irregularly lobulated and covered in part by dull gray epithelium. Shallow superficial areas of ulceration were common and occasionally confluent. On section the cut surface was dark brown. It showed no gross evidence of necrosis, hemorrhage, or extension into the underlying muscle. About the point of pedicle attachment to the wall, there were numerous, raised, purplish, "daughter" lesions that measured up to 1 cm. in diameter. The mucosa of the distal 7 cm. was gray and unremarkable. Adjacent to the tumor, it was diffusely purple in color. All of the attached regional lymph nodes were found to be slightly enlarged and deeply pigmented.

Fig. 1.

Fig. 2.

Figs. 1 and 2.—Barium contrast studies of esophagus showing filling defect near junction of middle and lower thirds.

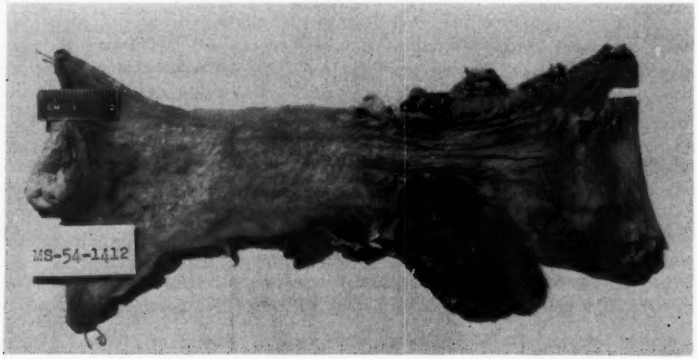

Fig. 3.—Segment of esophagus removed at operation containing polypiform melanocarcinoma with marked pigmentation of the distal regional lymph nodes and adjacent proximal mucosa.

Microscopic examination of numerous sections revealed essentially the same picture. The neoplasm was exceedingly cellular and showed marked anisocytosis, anisonucleosis, indistinct cell borders, frequent mitotic figures, and excessive extra- and intracellular brown pigment (Fig. 4).

The overlying epithelium was compressed, and a striking adjacent junctional change was present. Irregularly replacing the basal layer and extending slightly into the submucosa was a loose network of altered epithelial cells. These showed a wide range of variation in nuclear size, shape, and staining qualities, prominent nucleoli, markedly reduced cytoplasm, and both intra- and extracellular deposits of dark-brown pigment. A representative area is shown in Fig. 5.

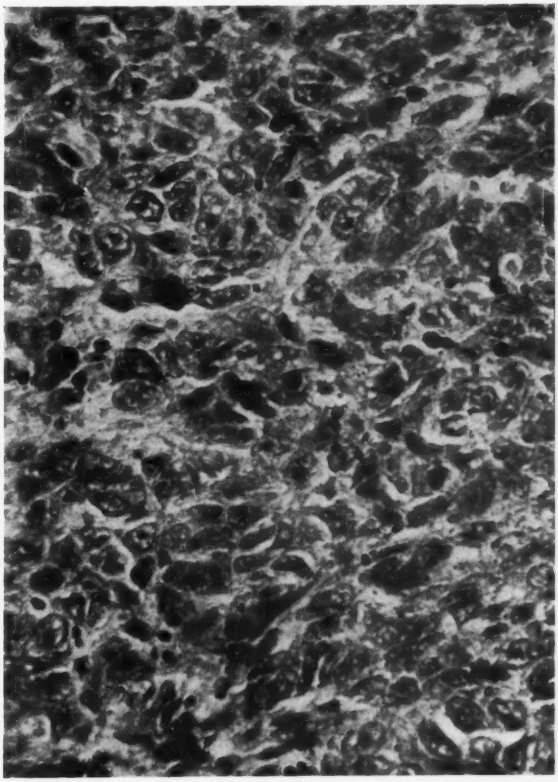

Fig. 4.—Photomicrograph of melanocarcinoma showing a wide range of nuclear variation and intra- and extracellular melanin formation (×430).

The tumor had extended laterally for varying distances into the submucosa and was found within lymphatic vessels. Examination of lymph node sections showed their deep pigmentation to be due to large quantities of melanin pigment within the reticuloendothelial cells and monocytic macrophages. One small focus of metastatic melanocarcinoma was identified. Stains for iron were negative, and the pigment was found to turn black in silver preparations. The final pathologic diagnosis was: melanocarcinoma of the eosphagus with adjacent junctional epithelial change and metastases to regional lymph nodes.

The immediate postoperative course was unremarkable except for an episode of auricular fibrillation that responded well to digitoxin.

Over the past fourteen months she has been seen periodically in the Outpatient Clinic. Anorexia, dysphagia, and weight loss have persisted, although two barium swallows have outlined a patent but slightly constricted operative site. Esophagoscopy has failed to demonstrate local recurrence. X-ray examinations of the chest and skeletal system have been negative for evidence of metastases.

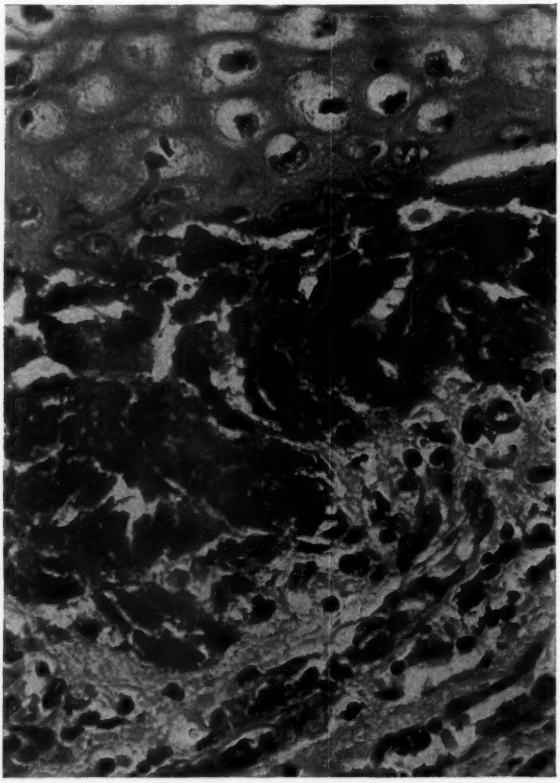

Fig. 5.—Photomicrograph of junctional change adjacent to melanocarcinoma. The cells of the basal layers of the mucosa have lost their polarity, become detached, and contain large quantities of melanin pigment (×430).

CLINICAL FINDINGS

A summary of the clinical data from the 17 reported cases is given in Table I. The patients' ages ranged from 40 to 71 years with an average of 60 years. The sex distribution was 11 males and 6 females with a ratio of 1.8 to 1. All of the patients were white except Sirsat's, who was a native of India, and the one described here, who was a Negro woman. The duration of symptoms extended from 5 to 52 weeks with an average of 21.1 weeks. We have omitted from these last computations Joliat's[2] and Robertson's[14] cases. In Joliat's report, the symptoms were described as being present for ten years, which seems

justifiably open to question. The reported duration in Robertson's case was one and one half years, but the clinical picture was somewhat altered by an associated adenocarcinoma of the colon and rectum.

The clinical picture was typical of a progressively obstructing lesion of the esophagus. An analysis of the symptomatology is given below.

Dysphagia was the most frequent complaint and resulted from the obstruction. This was always partial. It was associated with a sense of discomfort that included fullness of the epigastrium, substernal pressure, precordial burning, weight in the "pit of the stomach," and postprandial bloating. Pain caused by the act of swallowing and by the passage of food was not uncommon. It was most frequently located behind the sternum and occasionally radiated through to the back.

Weight loss was present in every case. It ranged from 3 to 45 pounds and was directly proportional to the duration of symptoms. Weakness commonly accompanied weight loss and became quite marked as clinical deterioration reflected the progressive growth of the tumor. Excessive sialorrhea was an interesting and frequent complaint, and it was not always associated with the intake of food or drink.

A secondary group of complaints consisted of cough, hoarseness, and orthopnea. As will be seen under the descriptions of the gross and microscopic pathology, these cannot readily be explained.

Physical signs of the disease were conspicuously absent. One patient presented a palpable left subclavian lymph node that subsequently proved to be metastatic melanoma.[8] In 2 others, melena was the only significant sign.

Laboratory findings were equally infrequent. Routine peripheral blood studies, urinalysis, and blood chemistries were within normal limits. Occult blood was present in the stools of 2 patients.

In every case, the general nature of the lesion was suspected from the history. Roentgenologic examinations, using barium as the contrast medium, were carried out in 13 patients. A filling defect was found in 11, and in 2 patients the lesion was completely overlooked. In one instance, the defect was found only after the third upper gastrointestinal series, and in another it was interpreted as a benign tumor.

A specific diagnosis was made by tissue examination in all instances. This was obtained by esophagoscopy and biopsy in 11 cases, following operation in 2 cases, and only at necropsy in 4 cases.

The therapy was symptomatic in 6 patients, radiation to the metastases in 1, and by surgical resection in 10. In Sirsat's case,[15] the patient signed himself out of the hospital and died at home two years later without further known treatment.

The reported over-all survival time varied from 3 days to 2 years with an average of 6.98 months. The given survival time for those patients whose lesions were removed surgically ranged from 3 days to 15 months with an average of 7.4 months. At the time the respective reports were made, however, 1 patient on symptomatic therapy was still alive 1 year after the diagnosis was made.

TABLE I. SUMMARY OF CLINICAL DATA OF THE SEVENTEEN REPORTED CASES OF MELANOCARCINOMA OF THE ESOPHAGUS

NUMBER	AUTHOR AND DATE	AGE	SEX	RACE	DURATION OF SYMPTOMS (WEEKS)	SITE OF LESION	THERAPY	SURVIVAL TIME		NOTE
								FROM ONSET OF SYMPTOMS	POST-OPERATIVE	
1.	Baur—1906	69	M	W	30	Upper 1/3	Symptomatic	30 weeks		Died shortly after admission to hospital; autopsy
2.	Joliat—1907	62	M	W	Given as 10 years	Lower 1/3	Symptomatic	Unknown		Died shortly after admission to hospital; autopsy
3.	Moersch and Broders—1927	59	M	W	5	Lower 1/3	Symptomatic	5 months		No autopsy
4.	Voss—1928	59	M	W	21	Lower 1/3	Symptomatic	23 weeks		Autopsy
5.	Jaleski and Waldo—1935	69	M	W	6	Lower 1/3	Radiation	10 weeks		Died 30 days after onset of radiation therapy; autopsy
6.	Puyo and Portmann—1950	63	M	W	34	Lower 1/3	Resection		No follow-up	
7.	Burnett and St. John—1951	55	F	W	26	Junction middle and lower 1/3	Resection		10 months	No autopsy
8.	Chalmagne—1951	68	F	W	39	Junction middle and lower 1/3	Symptomatic	1 year		Patient alive at time of report

9.	Fowler and Sutherland—1952	60	F	W	21	Lower ⅓	Resection		3 days	Autopsy
10.	Garfinkle and Cahan—1952	55	F	W	21	Upper ⅓	Resection		18 days	Autopsy
11.	Citterio—1953	67	M	W	13	Lower ⅓	Resection		15 months	No autopsy
12.	Bullock et al.—1953	71	M	W	13	Middle ⅓	Resection		4 months	Patient alive at time of report
13.	Boyd et al.—1954	63	M	W	10	Junction middle and lower ⅓	Resection		6 weeks	Patient alive at time of report
14.	Robertson—1954	58	M	W	Given as 1½ years	Lower ⅓	Resection		12 months	Patient also had cancer of colon and rectum; autopsy
15.	Sirsat—1955	40	M	Indian	52	Lower ⅓	Symptomatic	2 years		No autopsy
16.	Pomeranz and Garlock—1955	48	F	W	8	Junction middle and lower ⅓	Resection	54 weeks	1 year	Patient alive and well at time of report
17.	Loring and Zeppa—1955	61	F	N	17	Junction middle and lower ⅓	Resection		14 months	Patient alive at time of report

Four patients in whom resection was performed were still alive 6 weeks, 4 months, 1 year, and 14 months postoperatively. Three were symptom free. One of these patients was lost to follow-up.

The 1 patient who received radiation died within 30 days. The lesion had spread widely, and the therapy was ineffectual.

Seven of the 17 patients came to autopsy. In 4 of these, the true nature of the lesion was discovered only at that time.

Gross Findings.—The neoplasm was located in the lower third of the esophagus in 9 cases, at the junction of the middle and lower third in 5 cases, in the upper third in 2 cases, and in the middle third in 1. It most frequently presented as a polypoid tumor mass but, in one instance, had extended about two thirds of the distance around the circumference of the esophagus, and in 3 had completely encircled the lumen. Voss's report[4] described a bilobed, elongated mass that reached into the lumen of the stomach.

The typical lesion was a lobulated, pedunculated, firm, friable, black, rounded tumor mass with measurements that varied from 3 by 2 by 1 cm. to 7 by 6.8 by 2.5 cm. The pedicle averaged about 1 cm. in diameter and 2 cm. in length. The rounded surface of the neoplasm was generally smooth but was commonly the seat of small, shallow areas of ulceration that bled easily on contact with the esophagoscope. Smaller, pigmented, firm, and raised "daughter" metastases were common in the mucosa immediately surrounding the main tumor. In those instances where the main mass was large, the proximal esophagus was dilated.

The cut surface was usually found to be brown or gray-black in color with visible gray septa subdividing it. Central necrosis or hemorrhage was not common. As the tumor was usually separated from the esophageal wall by the length of the pedicle, gross evidence of invasion of the esophageal wall was usually not found. The one exception to this was the case of Puyo and Portmann,[6] where the melanocarcinoma had invaded the esophageal wall and had extended as a woody hard mass from the cardia of the stomach to a level just above the aortic arch.

Microscopic Findings.—Cellularity was marked. In only one lesion was a desmoplastic reaction described. In sections from four specimens, the tumor seemed to derive its blood supply through small vessels contained within the dividing fibrous septa.

Pleomorphism was the most striking cellular characteristic. The cells were described as being polygonal, large and elongated, round with long nuclei, and "sarcoma-like." The cytoplasm was basophilic, eosinophilic, or amphophilic. Fine cytoplasmic granules were occasionally present. In the more malignant lesions, little or no cytoplasm was visible.

Mitotic figures were present in all cases and very numerous in 3. In two specimens, meganucleosis was striking. Anisonucleosis and poikilonucleosis were found generally. Nuclear hyperchromatism and chromatin clumping were common findings. The cells were arranged in cords, clusters, fascicles, or alveolar patterns.

Iron-free intracellular pigment was found in 15 of the 16 cases. It was described in macrophages in 7 cases and lying free in the intercellular spaces in 4 cases. All authors concluded that this substance was melanin by the use of one or more of the following means: (1) the characteristic appearance and location in the hematoxylin and eosin stained sections; (2) the negative reaction with special stains for iron; (3) the final black color of the granules after staining with Bielschowsky's silver nitrate method; and (4) the slow blackening effect of hydrogen peroxide.

In 9 of the 17 cases, the melanocarcinoma had invaded the submucosa and extended under the epithelium. In 4 cases, it was specifically stated that the muscle was invaded, and in 4 cases no invasion was found. Lymphatic and blood vessel penetration was not uncommon. In two specimens, however, multiple sections failed to show vessels violated by malignant cells.

Junctional changes were found in 6 cases including the 1 reported here. These were usually found in the noneroded portions of the mucosa adjacent to the tumor. Their histology ranged from hyperpigmentation and a great increase in the number of clear cells of the basal layer, resembling that seen in lentigo of the skin, to a stage identical with a fully developed junctional nevus. Usually the germinal layer and deeper portion of the stratified squamous layer contained darkly pigmented cells lying loosely in vacuolated areas. Nucleoli were prominent and the nuclei were hyperchromatic. Mitotic figures were not striking.

Sites of Metastases.—A detailed examination of the lesion and surrounding structures was made in 14 of the 17 cases either after surgical resection or at autopsy. Of these, melanocarcinoma was found in the regional lymph nodes in 11.

The available information on more distant spread was obtained from those 7 patients who came to post-mortem examination. The lungs were most frequently involved, and melanocarcinomatous nodules of varying size were found in five instances. The liver and pancreas were the next most frequent sites, each being the seat of metastatic tumor in three instances. The gastrointestinal tract, brain, lumbar spine, pleura, peritoneum, lesser curvature of the stomach, retroperitoneal tissue, and left supraclavicular lymph nodes were involved in one instance each.

DISCUSSION

Primary melanocarcinoma arising in the esophagus is an uncommon and unusual lesion. The diagnosis in each of these 17 cases was made by tissue examination and is unequivocal. In every instance, a special effort was made to rule out a primary site elsewhere, and none was found. Several authors[10, 12, 13] have laid great stress on finding associated junctional epithelial changes as proof positive of autochthony, and in at least 6 of these 17 cases this transformation was present.

We, however, do not believe that this requirement is justified and agree with Robertson's observation[14] that the expanding neoplasm may well have

destroyed any junctional change in those 11 specimens where it was not found. Further support is gained when one considers the rare occasion in which the esophagus is the seat of a metastatic tumor.

A consideration of possible contributory etiological factors and some of the characteristic gross findings may be made together because of their intimate relationship. Two of the 17 cases had a definite history of trauma. Puyo and Portmann's patient,[6] two years prior to the development of the malignancy, accidentally swallowed petrol with a resulting severe esophagitis. Garfinkle and Cahan's patient[10] experienced a near-fatal esophagitis and mediastinitis six years previously, following the lodgment of a chicken bone. It is difficult to believe, however, that these two incidents played a significant role in the induction of the subsequent malignant lesion.

Since by the nature of this study we can only surmise the mechanisms involved, one of the more interesting possibilities is found in the examination of the physiology of the esophagus itself. It has been clearly shown[17] that, during the third stage of the deglutition, the bolus of food is carried quickly (5 or 6 seconds in man) through the esophagus to the stomach by primary and secondary peristaltic waves. The passage through the upper third is much more accelerated than through the middle and lower thirds because of the capacity of the striated muscle in its wall for rapid contractability. It is also generally accepted that chronic irritation may play a fundamental role in the pathogenesis of melanocarcinomas elsewhere.

It would then not be unreasonable to assume that the mucosa of the lower and middle thirds of the esophagus is subject to a certain amount of chronic irritation by the rapid propulsion of food through them, especially if the food is hot, spicy, or poorly masticated.

Some support of this observation is derived from the finding of fifteen of the seventeen lesions in lower and middle thirds of the esophagus. This reasoning may also be pertinent in epidermoid carcinoma of the esophagus.

Also of interest is the observed fact that thirteen of the seventeen tumors were clearly polypoid in nature. The frequent downward push of the peristaltic waves and of the esophageal stream offers a good explanation for this characteristic gross finding. The polypoid nature of this highly malignant neoplasm may in turn explain the limited invasion of the underlying esophageal wall and the complete absence of perforation as a complication.

The obvious question as to why few people develop melanocarcinoma in the presence of such common circumstances remains unanswered and must refer back to the more fundamental nature of the lesion.

If we then review the salient historical, physical, and laboratory findings in an attempt to assemble those features that might aid in the future diagnosis of this condition, the results are of limited value.

The history was always one of a slowly expanding and gradually obstructing mass. Except for finding gross or occult blood in the stool, routine laboratory examinations were unrewarding. Although it was not always appreciated, radiologic examination often indicated the nature of the lesion. It was usually easy to outline, and its lobulated, polypoid contour tended to differentiate it from the large majority of epidermoid carcinomas. On the basis of this tech-

nique, however, one could not rule out a papilloma of the epithelium, a fibroma, polyp, or myxoma of the connective tissue, or a leiomyoma or rhabdomyoma of the muscle coat. Using contrast media, the resulting filling defect in any of these conditions might be very similar in appearance. The value of this examination is lessened somewhat further by the fact that these latter lesions are almost as rare as melanocarcinoma.

It was found then that, although the true nature of the lesion can be suspected, a definitive clinical diagnosis can be made only by esophagoscopy, biopsy, and histologic examination.

From the information given previously it is quite clear that, if patients with this disease are not treated surgically, the prognosis is universally bad. Symptomatic and radiation therapy are of little value. In those patients in which the lesion was successfully resected, the postoperative follow-up was not sufficiently long to evaluate clearly this means of attack. The data indicate, however, that as is the case in any malignant tumor, if therapy is undertaken sufficiently early, especially before the tumor has distantly metastasized, the results may be relatively satisfactory.

SUMMARY

Seventeen cases of melanocarcinoma of the esophagus (16 from the world literature and 1 reported here) were studied in an attempt to consolidate all of the available clinical, diagnostic, pathologic, and prognostic data into a composite form. Possible contributory etiological factors were discussed.

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TRANSCAROTID AORTOGRAPHY

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THE roentgenographic visualization of the cardiovascular system using contrast media has proved of great value in the accurate diagnosis of various lesions of the heart and great vessels. Angiocardiography, with progressive visualization of all the chambers of the heart as well as the intrathoracic great vessels, has been useful particularly in the demonstration of congenital cardiovascular lesions of children. In adults, marked dilution of the injected contrast media in the blood stream and heavy x-ray penetration required for proper visualization has proved angiocardiography to be of limited application. Regional injection of concentrated contrast substances, through a properly placed needle or catheter, directly into the aorta and chambers of the heart has been used with increasing frequency. Abnormalities of the aorta, abnormal shunts, as well as valvular deformities, can be demonstrated by this method.

In 1929, Dos Santos and his associates[1] first described a satisfactory technique of translumbar abdominal aortography which is now a standard procedure of wide application. The first successful retrograde thoracic aortography was reported by Perez de Los Reyes and his co-workers in 1943.[2] A thin trocar was introduced into the left brachial artery and the radiopaque material was injected into the aorta against the arterial flow.

In 1948, Radner[3] described his technique of introducing a No. 7 to No. 9 F. cardiac catheter into the ascending aorta through the right or left radial artery. This method was developed further by Broden, Hanson, and Karnell.[4] Fifty cubic centimeters of 70 per cent Diodrast was injected manually in approximately 7 seconds. They suggested that more rapid injection of the contrast media could be obtained by using a mechanical pressure injection technique.

Burford and Carson,[5] in 1948, reported on the results of aortography performed in children. They exposed the left carotid artery and under direct visualization inserted a No. 10 cannula into the left common carotid artery and rapidly injected 30 to 50 c.c. of 70 per cent Diodrast. Excellent visualization of the aorta and its branches was obtained. Stephens[6] reported using an 18-gauge needle which was inserted into the exposed left common carotid artery with injection of 25 c.c. of 35 per cent Diodrast.

Because of difficulties encountered in using the radial artery for introduction of the cardiac catheter into the ascending aorta, Jönsson[7] abandoned this

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method of aortography and introduced a specially devised, double lumen, blunt cannula which was introduced percutaneously over a silver wire into the right common carotid artery and ascending aorta. Forty to 80 c.c. of a contrast solution could readily be injected into the aorta in 3 seconds.

In 1950, Helmsworth, McGuire, and Felson[8] utilized the brachial and ulnar collateral arteries as well as the femoral to introduce a polyethylene catheter, 50 to 70 cm. in length, into the ascending aorta. The inner diameter of the catheter was such that 8 to 30 c.c. of 70 per cent Diodrast could be injected through a 50 c.c. syringe manually in 0.7 to 1.8 seconds. Excellent visualization of the coronary vessels as well as the other branches of the aorta was obtained. Goodwin and co-workers[9] used a No. 10 F. ureteral catheter for the same purpose. Pierce,[10] in 1951, reported the use of a polyethylene tube threaded through a 17-gauge needle which in turn had been inserted into the femoral artery. Twenty to 25 c.c. of 70 per cent Diodrast was injected manually in 3 to 5 seconds.

In 1952, Wickbom[11] reported the results of aortography by direct puncture of the ascending aorta using a 13 cm. long, 1.8 mm. outside-diameter needle with manual injection of 30 to 40 c.c. of Diodrast. The time required was 3 seconds. Mediastinal hematomas occurred in several patients.

In 1954, Smith, Wilson, Cregg, and Klassen[12] reported a series of aortographies performed by percutaneous left ventricular puncture using a 17-gauge, 15 cm. needle. Twenty-five cubic centimeters of 70 per cent Diodrast was injected manually, requiring up to 3 seconds. Excellent contrast visualization of the aorta was obtained in some cases; however, the long time required for the injection prevented sufficient concentration of the contrast media to produce uniformly good aortograms.

The various techniques of aortography described in the literature were used in this Clinic with occasional excellent results but frequent failures. The difficulty of these methods is that it is impossible to inject a large enough amount of medium in the necessary second or less for good visualization of the aorta because of the small size and excessive length of the various needles and catheters. Difficulties are also encountered in the proper placement of the catheter and needle. Obliteration of the small arteries utilized for the insertion of the needles and catheters due to trauma and thrombosis is not infrequent.

A technique of thoracic aortography to be universally useful should consistently visualize the aorta from its origin to the diaphragm. The method should be safe, simple to perform, and require only surgical instruments and radiographic facilities standard in general hospitals. Rapid injection of contrast media into the ascending aorta just above the aortic valve by means of a large, short catheter inserted through the exposed right common carotid artery appeared to us to be the ideal method of aortography. Intimal damage to the aorta and carotid artery due to the presence of the catheter or contrast

media would be negligible because of the large size of these vessels and the rapid flow of blood in this region. Coronary and cerebral artery filling, however, should be considered possible hazardous sequelae.

Highly concentrated solutions of contrast media used for angiocardiography at the present time may produce severe damage to tissues by acute anoxia, immediate or late toxicity, or direct chemical action. In patients without anoxemia or hypotension, brief coronary artery filling with contrast media appears to be well tolerated; however, cerebral vessel filling may produce

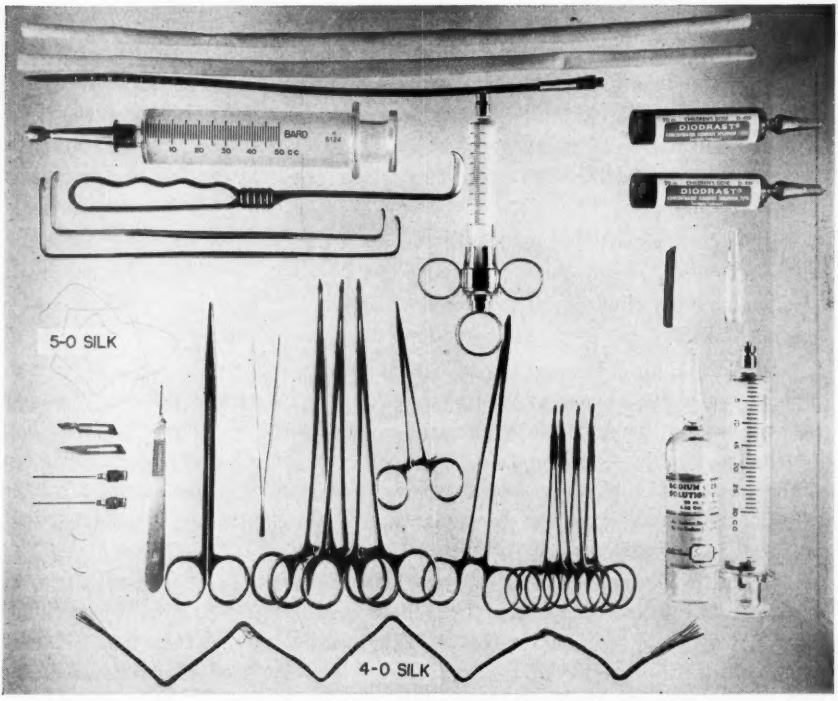

Fig. 1.—Aortography tray.

transient or irreversible damage. Cerebral vessel filling can be kept to a minimum by occlusion of both common carotid arteries at the time of actual contrast injection.

METHOD

The catheter* developed for aortography is a calibrated, radiopaque, 14 F., 35 cm. long, woven-silk catheter with a tapered lip and a Luer-Lok syringe at the proximal end (Fig. 1).

The right common carotid artery is exposed through a 2-inch incision in the skin crease at the median border of the sternocleidomastoid muscle after

*Manufactured by C. R. Bard, Inc., Summit, N. J.

local injection of 1 per cent procaine solution. Following exposure of the common carotid artery, two cigarette-size Penrose drains are passed around the artery allowing it to be brought into the field. Traction on the rubber drains placed at each end of the exposed artery effectively occludes this vessel and a 3 mm. longitudinal incision in the wall of the artery will allow passage of the tip of the catheter into the innominate artery and ascending aorta. With insertion of the catheter to the 12 to 16 cm. mark, the tip will be found on fluoroscopy to be located 2 to 3 cm. above the aortic valve (Fig. 2).

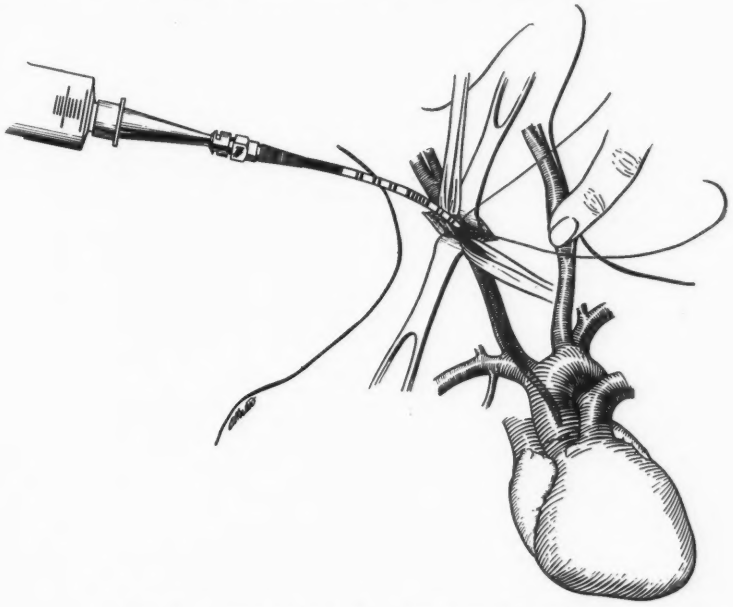

Fig. 2.—Schematic drawing of aortography technique.

Using a 50 c.c. Toomey syringe, 40 c.c. of 70 per cent Diodrast is injected manually into the aorta with the left common carotid artery occluded by finger pressure (Fig. 2). When the plunger is within 10 cm. of emptying the syringe, x-ray exposures are made either by manual change of the cassettes, or preferably, using a Fairchild film changer. On completion of the aortography the catheter is withdrawn and the incision in the carotid artery closed with a continuous suture using 5-0 silk on an Atraumatic needle. With release of tension in the Penrose drain, flow through the carotid artery resumes. The skin incision is closed with silk.

Twenty aortograms have been performed using the method just described with good results (Figs. 3 through 7). A small hematoma developed in 1 patient due to bleeding from a small cervical vein which had not been ligated properly during exposure. In 1 patient, no visualization was obtained due to mechanical failure.

Fig. 3.

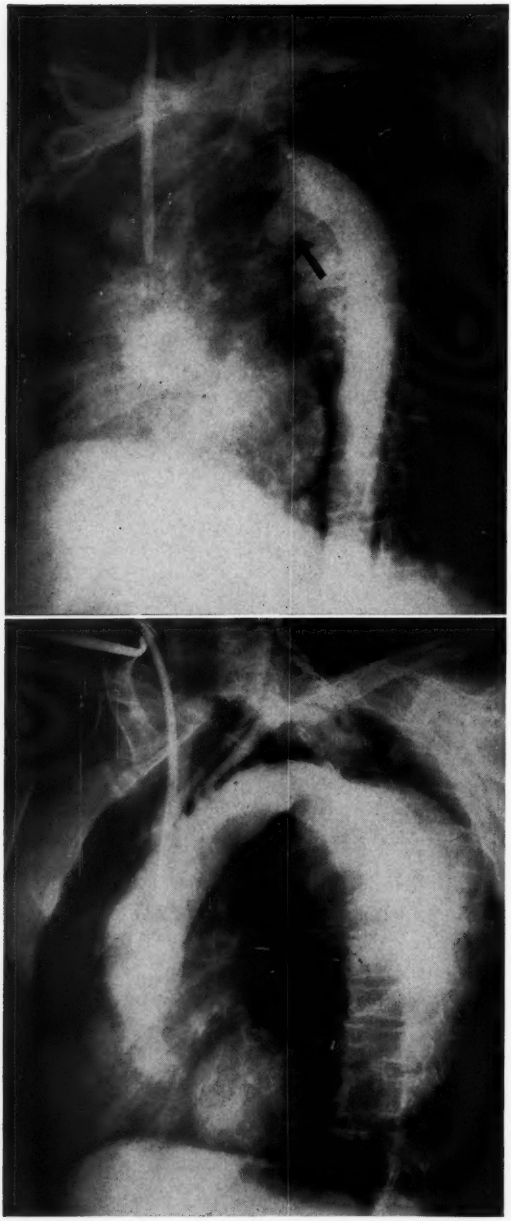

Fig. 4.

Fig. 3.—Aneurysmal dilatation of ductus arteriosus.
Fig. 4.—Aneurysm of descending aorta.

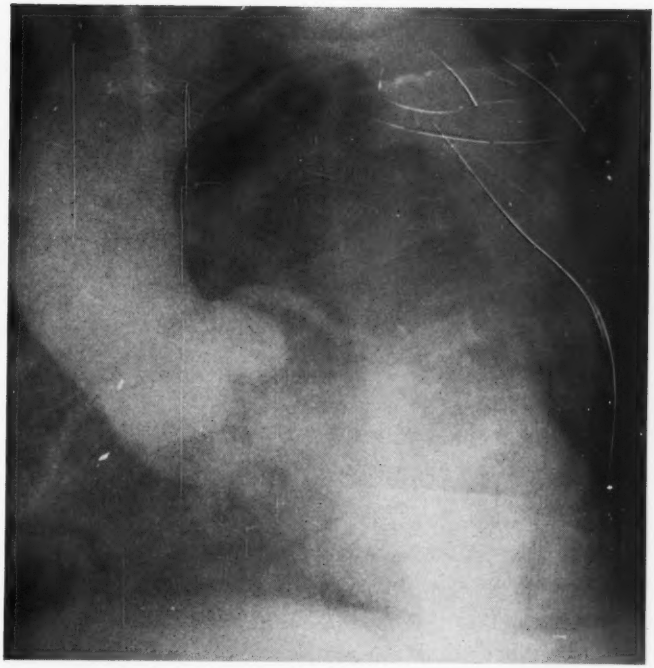

Fig. 5.—Retrograde ventricular filling due to aortic insufficiency.

Fig. 6.—Coarctation of aorta.

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Fig. 7.—Right subclavian artery occlusion.

SUMMARY

A method of transcarotid thoracic aortography utilizing a catheter placed into the ascending aorta has been described. Aortography by this method using 70 per cent Diodrast has given excellent visualization of the entire thoracic aorta.

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THE PHYSIOLOGIC EFFECTS OF FIBROTHORAX AND THE FUNCTIONAL RESULTS OF SURGICAL TREATMENT

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ST. ALBANS, N. Y.

INTRODUCTION

PLEURAL decortication is an established method for restoring the apposition of the pleural surfaces, thus obliterating an abnormal pleural space. In addition to meeting this therapeutic objective, the operation frequently results in significant improvement in the respiratory status of the patient. A number of studies have appeared in which the procedure is evaluated from a functional point of view.[1-5] A concise review of these may be found in the introductory paragraphs of the publication by Patton and his associates.[3]

This report concerns an additional study of the physiologic effects of pleural abnormalities and their surgical treatment. Few patients with lungs imprisoned by tuberculous or nontuberculous pleural peels have been evaluated comprehensively. Some of the most complete studies have suffered from a lack of pre- to postoperative comparisons[1, 4] and in others the data are limited to ventilation, vital capacity, and oxygen uptake.[2, 3] Among the papers referred to, only 4 patients are cited[1, 5] in whom pre- and postoperative tests include total lung capacities, bronchospirometry, and gas analysis of arterial blood.

The data recorded from the present 11 patients pertain to pre- and postoperative unilateral and bilateral ventilation and total lung capacities as well as to characteristics of gas exchange. The measurements of the maximum diffusing capacity and the determinations of the unilateral residual volume have not, to our knowledge, been reported previously in such patients.

From the Cardiopulmonary Function Laboratory, United States Naval Hospital, St. Albans, N. Y.

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MATERIAL

Eleven patients for whom decortication was the major thoracic surgical procedure were studied in the Cardiopulmonary Function Laboratory of the United States Naval Hospital, St. Albans, New York. A bacteriologic diagnosis of tuberculosis was established in 5 of these and in an additional patient (No. 9) the diagnosis of tuberculosis was made on histologic grounds without bacteriologic verification (Table I). In the other 5 patients, the constricting peel was considered to be nontuberculous in origin. A summary of other pertinent clinical data is included in Table I. Ten of the 11 patients were men; only 1 of these exceeded 35 years of age. There were nine Caucasians and two Negroes.

The involvement was unilateral in all patients. The right chest was the site of the pathology in 5 patients and the left side in 6. The duration of the disorder prior to operation ranged from two months in Patient 4 to thirteen years in Patient 6. In all but 2 patients the abnormality had been recognized less than one year prior to surgery. The period of convalescence before the postoperative study was three months or less in all but three instances. Most of the patients, therefore, were young men with a unilateral pleural membrane uncomplicated by parenchymal involvement in whom the postoperative study was carried out relatively early after decortication.

Four patients were selected in order to illustrate (a) physiologic improvement following decortication for nontuberculous empyema (Patient 2, Figs. 1*A* and 1*B*) and tuberculous empyema (Patient 11, Figs. 2*A* and 2*B*); (b) functional changes following decortication performed for long-standing parenchymal disease treated with pneumothorax (Patient 8, Figs. 3*A* and 3*B*); and (c) unfavorable results of operation in a patient with only moderate preoperative impairment due to a chronic "nontuberculous" pleural membrane (Patient 3, Figs. 4*A* and 4*B*).

Clinical data pertaining to these 4 illustrative cases follow in summary form.

CASE REPORTS

Patient 2, a 20-year-old white man, developed fever and extreme chest pain in April, 1952. Physical examination and roentgenograms revealed the presence of a left-sided pleural effusion. Under chemotherapy he became asymptomatic and afebrile but the roentgenographic signs of the effusion persisted. In July, a thoracentesis yielded 900 c.c. of fluid which on smear and culture was negative for acid-fast bacilli and other pathogenic organisms.

A left thoracotomy was performed in August, 1952. A chronic empyema was found with the lung entrapped by a thick peel. Decortication was done following which the lung re-expanded well. The postoperative course was uneventful.

Patient 11, a 23-year-old Negro man, was well until April, 1953, when he developed pain in the left chest on deep inspiration. Physical examination and a roentgenogram of the chest showed a left pleural effusion. Fluid aspirated was positive for acid-fast bacilli on culture. He was treated with bed rest, repeated thoracenteses, streptomycin and para-aminosalicylic acid. In October, 1953, decortication was performed. Two weeks after the operation, the seventh intercostal space was explored, an extrapleural abscess cavity was found and the involved cartilage and rib were resected. The postoperative course was uneventful.

Patient 8, a 41-year-old white man, was first found to have pulmonary tuberculosis in 1944 with involvement of the right lung. He was treated with right phrenic crush and nine

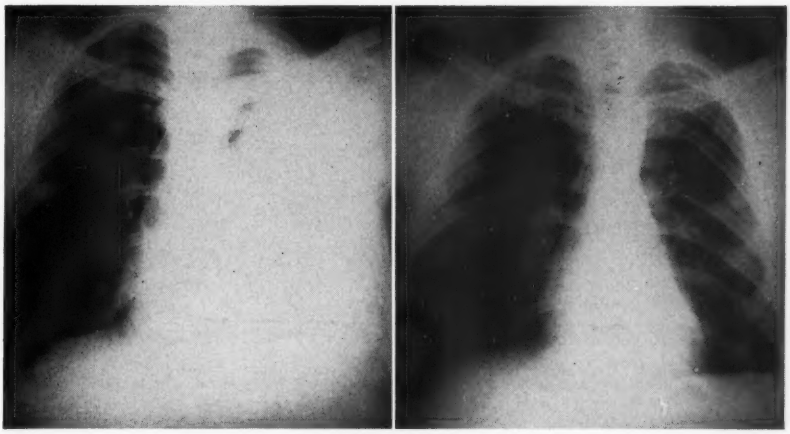


Fig. 1*A*.—Chest roentgenograms of Patient No. 2 taken before (left) and after (right) decortication of the left lung for a nontuberculous empyema. Corresponding functional data are presented in Fig. 1*B*.

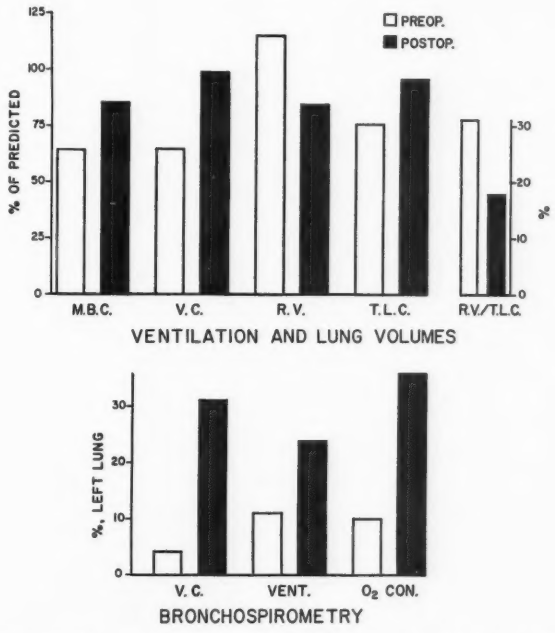


Fig. 1*B*.—Preoperative (clear bars) and postoperative (solid bars) function data of Patient 2. Note the improved maximum breathing capacity (M.B.C.) and unilateral participation in ventilation (Vent.), the increased vital capacity (V.C.) and total lung capacity (T.L.C.), and the augmented contribution of the left lung to oxygen consumption (O_2 Con.). The fall in residual volume (R.V.) is atypical (see Figs. 2*B* and 3*B*).

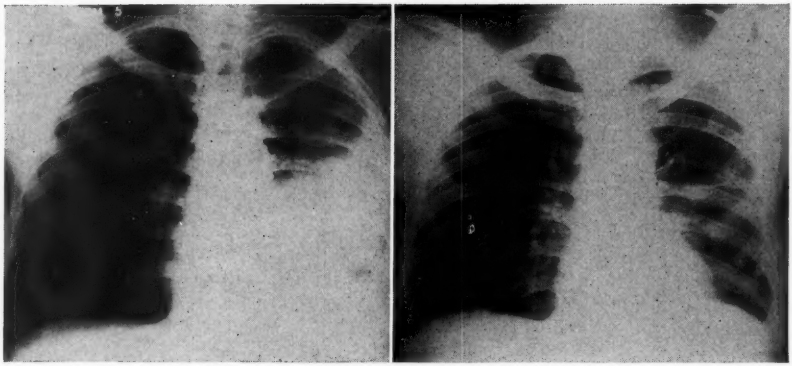


Fig. 2*A*.—Chest roentgenograms of Patient 11 taken before (left) and after (right) decortication of the left lung for a tuberculous empyema. Corresponding functional data are presented in Fig. 2*B*.

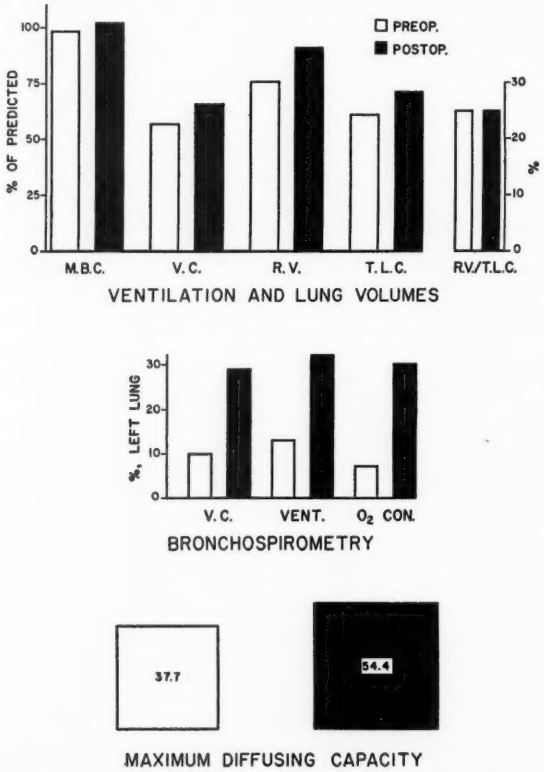


Fig. 2*B*.—Preoperative (clear bars) and postoperative (solid bars) function data of Patient 11. At the time of the postoperative study the bronchospirometric data were more sensitive indices of operative result than were the bilateral studies. The augmented contribution of the left lung to oxygen uptake (O_2 Con.) was associated with an increase in the maximum diffusing capacity. Note that the pre- to postoperative changes in the function of the left lung compare with those established for the left lung of Patient 2 (Fig. 1*B*) in whom the empyema was nontuberculous.

months of bed rest. Reactivation of the tuberculous process was noted in 1946 and from then until 1951 he was treated with right-sided artificial pneumothorax with refills of air at intervals of four weeks. Operations for lysis of adhesions were performed in 1947 and in 1950. Following the procedure in 1947, a persistent right pleural effusion developed. Aspirates of this effusion were positive on culture for acid-fast bacilli on several occasions. During 1951 he received a nine-month course of streptomycin and isonicotinic acid hydrazide.

In 1953, on admission for decortication, physical examination revealed dullness, decreased breath sounds, and diminished fremitus on the right side. Cultures of pleural aspirates were negative for acid-fast bacilli; one guinea pig innoculation, however, was positive. After the patient had been treated with streptomycin, para-aminosalicylic acid, and isonicotinic acid hydrazide for one month, a decortication and wedge resection of the posterior segment of the right upper lobe were performed. The lung expanded well following the operation, filling the pleural space. The postoperative course was uneventful.

Patient 3, a 24-year-old white man, complained of pain in the left chest in February, 1953. Although roentgenograms were reported to be normal, physical examination revealed a harsh friction rub on the left side. He was treated with bed rest and Aureomycin. In March, the presence of a left pleural effusion was detected. The friction rub disappeared but roentgenograms suggested the presence of loculated fluid in the lower left chest. Thoracentesis yielded a serosanguineous fluid which was negative for acid-fast bacilli on smear, culture, and guinea pig innoculation.

At thoracotomy in October, 1953, a thick pleural peel was found to extend from the lateral costophrenic sulcus to the apex of the left chest. Removal of this tissue was followed by expansion of the lung so that it filled the left hemithorax. The postoperative course was uneventful.

METHODS

Conventional methods were used for the various tests of pulmonary function. The maximum breathing capacity was measured by collecting the expired air in a Douglas bag and passing the contents through a gas meter; the best of three fifteen-second trials was recorded. Ventilation and oxygen consumption at rest and the subdivisions of the vital capacity were recorded by closed-circuit spirometry, the best of three values for vital capacity being incorporated in Table II. A modification of the Darling[6] open-circuit technique was used in measuring the functional residual capacity. The figures recorded are the mean of two analyses which checked within 10 per cent. The mixing index, the concentration of nitrogen remaining in "alveolar" air after the patient had breathed oxygen for seven minutes, is also the mean of two values. The expiratory reserve was subtracted from the functional residual capacity in computing the residual volume.

Bronchospirometry was performed after local anesthetization with 1 per cent Pontocaine. A Carlens[7] catheter was inserted into the upper larynx under mirror visualization and gently rotated through the glottis. Tracings of unilateral ventilation and oxygen consumption were recorded for three or more minutes following stabilization of the breathing pattern. The patient was then instructed to deliver his expiratory reserve and, following restoration of the original midposition, his inspiratory capacity. Where measurements of the unilateral functional residual capacity were to be done, the initial record was obtained with the patient breathing room air. A second tracing was inscribed during oxygen breathing after these volumes had been measured. The open-circuit method was applied simultaneously to both lungs individually in measuring the unilateral functional residual capacity[8] (Table III).

Ventilation-perfusion relationships and the maximum diffusing capacity (Table IV) were measured by the methods described by Lilienthal and his associates,[9] and by Riley and co-workers.[10, 11] Briefly, the expression for the physiologic dead space ($V^e_D/V_T \times 100$) is a measure of the fraction of the tidal volume delivered both to parts of the respiratory tract unspecialized for diffusion of respiratory gases (anatomic dead space) as well as to alveoli which are poorly perfused relative to their ventilation. The figure for venous admixture ($\dot{Q}_{va}/\dot{Q}_t \times 100$), on the other hand, indicates the fraction of the cardiac output either by-passing the lungs or circulating through alveoli in which ventilation is poor relative to perfusion.

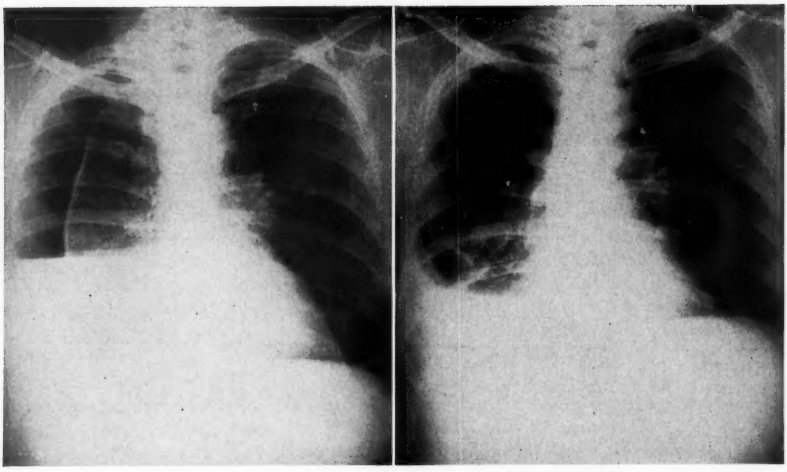
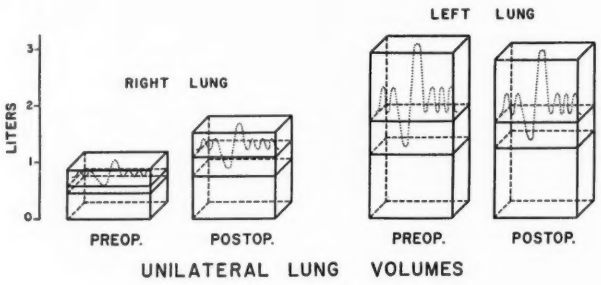


Fig. 3*A*.—Chest roentgenograms of Patient 8 taken before (left) and after (right) decortication of the right lung. There had been pneumothorax intermittently for nine years and persistent tuberculous pleural effusion for seven years. Corresponding functional data are presented in Fig. 3*B*.



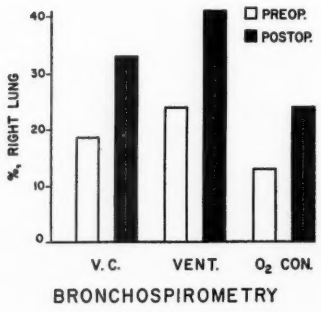


Fig. 3*B*.—Pre- and postoperative unilateral function data of Patient 8. Three-dimensional figures indicate the subdivisions of the total volume of each lung. A tracing of the spirogram identifies the volume of the lung at the end-expiratory position (Functional Residual Capacity or F.R.C.), after maximal inspiration (Total Lung Capacity), and following a maximal expiration (Residual Volume or R.V.). These volumes are labeled in Fig. 4*B*. Note the increase in all volumetric compartments of the right lung in consequence of decortication and re-expansion. Bronchospirometry indicates an augmented contribution of this lung to vital capacity (V.C.), ventilation (Vent.), and oxygen uptake (O_2 Con.) despite the prolonged duration of right pleural disease.

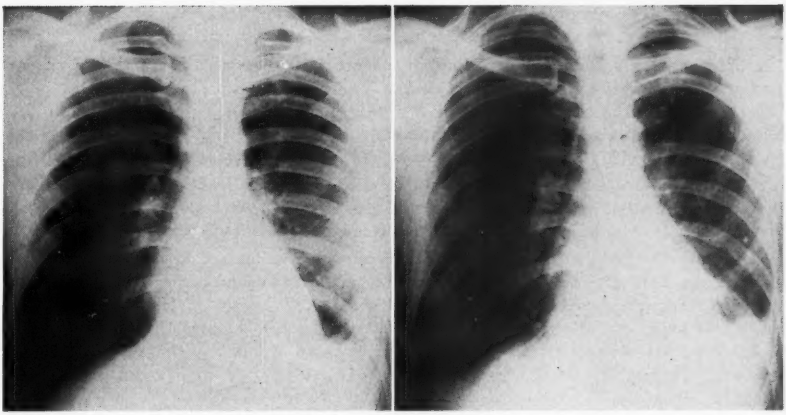
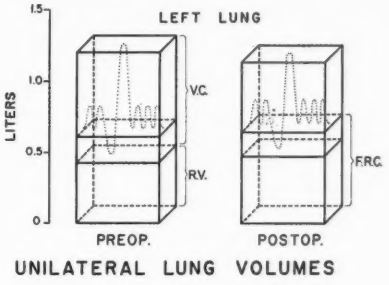
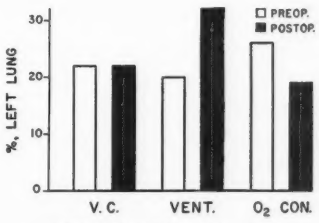


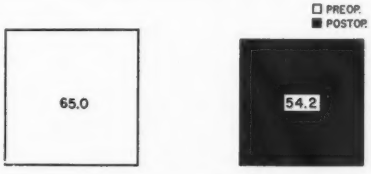
Fig. 4*A*.—Pre- and postoperative chest roentgenograms of Patient 3. A sterile pleural effusion had persisted on the left for seven and one-half months. The postoperative film was made three weeks after decortication, coincidentally with the postoperative studies represented in Fig. 4*B*.



UNILATERAL LUNG VOLUMES



BRONCHOSPIROMETRY



MAXIMUM DIFFUSING CAPACITY

Fig. 4*B*.—Pre- and postoperative function data of Patient 3. The interpretation of the volumetric figures corresponds to that for Fig. 3*B*. At the time of the postoperative study, the volumetric compartments of the left lung were virtually identical with those measured preoperatively. Bronchospirometry indicates the moderate preoperative deficit, the improved contribution of the left lung to ventilation, and the further impairment in oxygen consumption. The latter was associated with a fall in the maximum diffusing capacity. V.C., Vital Capacity; R.V., Residual Volume; F.R.C., Functional Residual Capacity.

If, in patients with normal alveolar-capillary membranes and normal alveolar oxygen partial pressures, one assumes that peripheral blood is a mixture of two streams, one being mixed venous blood and the other arterial blood in equilibrium with alveolar air, the venous admixture figure indicates the fraction of mixed venous blood which, if added to the equilibrated arterial blood, would account for the peripheral arterial saturation actually measured. Patients in whom variations in ventilation-perfusion relationships in different parts of the lungs are abnormally great have dead space ventilations exceeding 30 per cent of the tidal volume and venous admixture components above 6 per cent.

The diffusing capacity is the amount of oxygen passing across the alveolar-capillary membrane per unit of pressure difference between the two sides of this membrane. It is obtained by measuring the oxygen consumption and deriving the effective partial pressure (tension) of oxygen in alveoli and in pulmonary capillaries. The alveolar value is calculated by solving the alveolar equation.[10] The capillary tension is found by measuring the partial pressure of oxygen in arterial blood (Pa_{O_2}) when it closely approximates that in the pulmonary capillaries. Circumstances under which this is true are created by reducing the oxygenation of the patient's peripheral arterial blood; this is usually accomplished by a combination of exercise and breathing a gas mixture abnormally low in its content of oxygen. From the alveolar and capillary oxygen partial pressures and from an assumed figure for the saturation of mixed venous blood, it is possible to derive a mean value for the oxygen tension gradients existing along the course of the pulmonary capillary. The diffusing capacity is the oxygen consumption divided by this mean gradient. The *maximum* diffusing capacity for a given individual is reached when oxygen consumption is increased to approximately 1,200 c.c. per minute.[12] Under these circumstances, and when the permeability of the alveolar-capillary membrane is not altered by disease, the diffusing capacity is a function of the maximal dimensions of the alveolar-capillary bed.[13] The maximum diffusing capacities in nine young men, with minimal or no pulmonary pathology, studied in this laboratory ranged from 68 to 86 with a mean of 76.[13]

Blood gas tension analyses were done by the bubble-equilibration technique[14] and the composition of expired gases was determined with the Scholander apparatus.[15] Blood gas contents and the concentrations of nitrogen in samples of air were measured by the Van Slyke manometric technique.

Lung volumes were corrected to body temperature, ambient pressure, saturated with water vapor (BTPS). The nomenclature used in referring to functional data is that suggested for workers in the field.[16]

The following abbreviations appear in Tables II and IV:

Ventilation, Bil., L./m./M² B.S.A.—Bilateral ventilation in liters per minute per square meter of body surface area, BTPS

Ventilation, Rt. %, Lt. %—Contribution of each lung to total ventilation in per cent

M.B.C., L./m.—Maximum breathing capacity in liters per minute, BTPS

M.B.C., % of Pred.—The maximum breathing capacity as per cent of the predicted value

V.C.—Vital capacity

R.V.—Residual volume

T.L.C.—Total lung capacity

F.R.C.—Functional residual capacity

R.V./T.L.C.—Ratio of the residual volume to the total lung capacity in per cent

F.R.C./T.L.C.—Ratio of the functional residual capacity to the total lung capacity in per cent

Mixing Index, Vols. % N_2—Mixing index in volumes per cent nitrogen

BP–47—Barometric pressure minus correction for water vapor tension of air saturated at body temperature, in millimeters of mercury

$F_{I_{O_2}}$—Concentration of oxygen in inspired air

$F_{E_{CO_2}}$—Concentration of carbon dioxide in expired air in per cent

$\dot{V}$—Total ventilation in liters per minute, BTPS

f—Respiratory frequency (breaths per minute)

R—The gas exchange ratio or respiratory quotient, i.e., carbon dioxide output divided by the oxygen consumption

Pa_{CO_2}—Partial pressure of carbon dioxide in arterial blood in millimeters of mercury

Ca_{CO_2}—Cubic centimeters of carbon dioxide contained in 100 cubic centimeters of arterial blood

$P_{A_{O_2}}$—Partial pressure of oxygen in alveolar air in millimeters of mercury

Pa_{O_2}—Partial pressure of oxygen in arterial blood in millimeters of mercury

Sa_{O_2}—Oxyhemoglobin saturation of arterial blood in per cent

$\dot{V}_{O_2}$—Oxygen consumption in cubic centimeters per minute, STPD (standard temperature and pressure, dry)

V^c_D, Total, c.c.—Physiologic dead space volume in cubic centimeters, corrected for apparatus dead space

V^c_D, M^2, c.c.—Physiologic dead space volume in cubic centimeters per square meter of body surface area

$(V^c_D/V_T) \times 100$—Ratio of dead space to tidal volume in per cent

$(\dot{Q}_{va}/\dot{Q}_t) \times 100$—Ratio of the venous admixture to cardiac output in per cent

RESULTS

Ventilation and Lung Volumes (Tables I and II)

The evaluation of the 11 patients with respect to ventilation and lung volumes (Table II) is presented below under three headings: (1) the effect of a constricting pleural peel, (2) the effect of operation, and (3) the postoperative status.

1. Effect of a Constricting Pleural Peel.—Ventilation at rest was abnormal in only 1 patient (No. 2). However, the contribution of the affected lung to ventilation was abnormally low in all patients studied preoperatively (below 40 per cent for the right lung in patients with involvement on the right side and less than 30 per cent for the left lung where this was the affected side). The *maximum breathing capacity* was below 90 per cent of the predicted value in 9 of the 11 patients and below 80 per cent of predicted in 7. This test was therefore a more useful index for detecting abnormalities in bilateral ventilation than was ventilation at rest.

Lung volume determinations indicated a restriction of the vital capacity below 80 per cent of the predicted value in 7 of the 11 patients, no elevation of the residual volume in excess of 140 per cent of predicted, and a decrease of the total lung capacity below 80 per cent of predicted in 7 patients. In only two instances was the ratio of the residual volume to the total lung capacity abnormally high (over 30 per cent). The vital capacity of the affected lung was grossly abnormal (below 40 per cent on the right or 30 per cent on the left) in each of the 9 patients with preoperative studies.

The *mixing index* was normal in all patients.

Comparison of the patients in the tuberculous and nontuberculous groups indicated *no striking differences* with respect to performance on these tests.

TABLE I. BODY CHARACTERISTICS AND CLINICAL DATA IN 11 PATIENTS TREATED BY PULMONARY DECORTICATION

PATIENT NUMBER	AGE	SEX	RACE	B.S.A.	DIAGNOSIS	SIDE	DURATION (MONTHS)	TBC OR NON-TBC	PARENCHYMAL LESION	BACTERIOLOGY	POSTOPERATIVE COMPLICATIONS	SECOND STUDY (MOS. POSTOP.)
1	21	M	Cauc.	1.79	Empyema, organism undeter.	Lt.	4	Non	No	–	Complete paralysis, lt. hemidiaphragm; empyema	8½
2	20	M	Cauc.	1.97	Empyema, chronic, nontubere.	Lt.	4	Non	No	–	None	10
3	24	M	Cauc.	1.92	Pleurisy, chronic, organism undeter.	Lt.	7½	Non	No	–	None	¾
4	33	M	Cauc.	2.03	Empyema, organism undeter.	Rt.	2	Non	No	–	None	1½
5	33	M	Negro	1.73	Pleurisy, chronic, organism undeter.	Rt.	4	Non	No	–	None	2
6	38	F	Cauc.	1.54	Pleurisy, tubere.; pulm. TBC, RUL, sup. seg. RLL, inact.	Rt.	13 yrs.	TBC	Yes, not resected	+	None	5
7	22	M	Cauc.	2.06	Pleurisy, tubere., chronic; arthritis, tubere., lt. knee	Rt.	4½	TBC	No	+	None	2½
8	41	M	Cauc.	2.00	Pleurisy, tubere., chronic; pulm. TBC, mod. adv., chronic	Rt.	7 yrs.	TBC	Yes, removed by wedge resection	+	None	2½
9	22	M	Cauc.	2.04	Pleurisy, tubere., chronic	Lt.	8½	TBC	No	–	None	2½
10	22	M	Cauc.	1.70	Empyema, tubere.; pulm. TBC, minimal	Lt.	6	TBC	Yes, removed by wedge resection	+	Bronchopleural fistula	2¼
11	23	M	Negro	1.78	Empyema, tubere., pulm. TBC, mod. act., RUL; TBC of bone, 7th costal cartilage	Lt.	6	TBC	Yes, not resected	+	None	3

TABLE II. PRE- AND POSTOPERATIVE UNILATERAL AND BILATERAL VENTILATION AND LUNG VOLUMES IN 11 PATIENTS TREATED BY PULMONARY DECORTICATION

PATIENT NO.		AFFECTED SIDE	VENTILATION					LUNG VOLUMES									VOLUMETRIC RATIOS, %		MIXING INDEX	OXYGEN UPTAKE	
			AT REST			MBC		V.C.				R.V.		T.L.C.		F.R.C.					
			BIL., L/m /M² BSA*	RT. (%)	LT. (%)	L/m	% OF PRED.	BIL. C.C.	% OF PRED.	RT. (%)	LT. (%)	BIL. C.C.	% OF PRED.	BIL. C.C.	% OF PRED.	BIL. C.C.	R.V./ T.L.C.	F.R.C./ T.L.C.	VOLS. % N_2	RT. (%)	LT. (%)
1	Pre	Lt.	3.2	--	--	79	58	2740	60	--	--	1099	96	3839	68	1813	29	47	1.35	--	--
	Post		4.6	69	31	99	72	3235	71	80	20	1473	129	4708	82	2209	31	47	1.14	74	26
2	Pre	Lt.	5.0	89	11	96	64	3029	65	96	4	1363	117	4392	76	1992	31	45	0.68	90	10
	Post		4.9	76	24	130	86	4580	99	69	31	975	84	5555	96	1920	18	35	0.52	64	36
3	Pre	Lt.	3.2	80	20	92	65	3331	74	78	22	1104	98	4435	79	1924	25	43	0.86	74	26
	Post		4.4	68	32	129	91	3005	67	78	22	1360	121	4365	78	2070	31	47	0.98	81	19
4	Pre	Rt.	3.7	38	62	159	113	3607	85	30	70	1483	139	5090	96	2072	29	41	1.10	37	63
	Post		6.5	57	43	153	109	3822	90	38	62	1761	166	5583	105	2281	32	41	0.65	53	47
5	Pre	Rt.	3.3	36	64	101	84	2242	57	20	80	759	77	3001	61	1304	25	43	0.98	24	76
	Post		3.3	44	56	145	121	2862	73	31	69	879	89	3741	76	1389	23	37	0.68	50	50
6	Pre	Rt.	3.8	--	--	69	84	2501	90	--	--	1070	126	3571	98	1613	30	45	1.35	--	--
	Post		2.4	55	45	85	101	2443	88	40	60	1232	145	3675	101	1782	34	48	3.23	24	76
7	Pre	Rt.	4.6	11	89	73	47	2375	49	8	92	784	65	3159	53	1131	25	36	0.61	17	83
	Post		3.9	41	59	144	93	3096	64	36	64	2061	172	5157	86	2623	40	51	0.55	40	60
8	Pre	Rt.	4.4	24	76	62	48	3310	81	19	81	1710	137	5020	94	2405	34	48	1.59	13	87
	Post		3.4	41	59	67	52	3415	84	33	67	1885	150	5300	100	2635	35	50	2.24	24	76
9	Pre	Lt.	6.4	78	22	120	78	4115	90	85	15	740	65	4855	85	1625	15	33	0.60	82	18
	Post		6.3	68	32	116	76	4180	91	71	29	1321	115	5501	96	2121	24	39	0.53	84	16
10	Pre	Lt.	5.3	94	6	75	59	2788	64	91	9	994	92	3782	70	1633	26	43	1.14	93	7
	Post		4.5	86	14	106	83	3234	74	78	22	1281	118	4515	83	2060	28	46	0.74	82	18
11	Pre	Lt.	4.1	87	13	131	98	2546	57	90	10	846	76	3392	61	1397	25	41	0.99	93	7
	Post		3.6	68	32	135	102	2964	66	71	29	1016	91	3980	71	1790	25	45	0.76	70	30

*See text under "Methods" for explanations of abbreviations used.

Summary: Restrictions of ventilation existed on the side of the lesion in all patients with bronchospirometric measurements. The total vital capacity was usually abnormally low and the unilateral vital capacity, where measured, was invariably low. The residual volume was also commonly reduced; it infrequently comprised a larger proportion of the total lung capacity than normal. No instance of impaired intrapulmonary mixing was found. No clear distinction could be made between patients on the basis of etiology.

2. Effect of Operation.—Ventilation at rest was found to increase by 15 per cent or more in 3 and decrease by 15 per cent or more in 5 patients, no significant change being noted in the other 3 patients. The contribution of the affected lung to ventilation increased by 8 per cent or more in each of 9 patients with pre- to postoperative comparisons (mean increase 15 per cent, maximum 30 per cent, minimum 8 per cent). The *maximum breathing capacity* increased by more than 15 L. (maximum, 71 L.; minimum, 16) in 7 of the 11 cases. In the other 4 the pre- to postoperative change was 6 L. or less.

The *vital capacity* increased by 16 per cent* or more (maximum 51 per cent, minimum 16 per cent) in 6 patients. In the remaining 5, the change was 10 per cent or less and was not considered significant. The residual volume increased by 15 per cent or more (maximum 163 per cent, minimum 15 per cent) in 9 patients, fell by more than 15 per cent in 1 patient, and remained unchanged (10 per cent) in 1. The total lung capacity increased by 10 per cent or more (maximum 63 per cent, minimum 10 per cent) in 8 patients and was insignificantly changed (less than 10 per cent) in the other 3. The ratio of the residual volume to the total lung capacity was increased by more than 3 per cent in 4 patients, fell by more than 3 per cent in 1, and was changed by less than 3 per cent in the remaining 6. Eight of 9 patients with pre- to postoperative unilateral vital capacity determinations showed an increase in the per cent contributed by the affected lung exceeding 8 per cent (mean 17 per cent, minimum 8 per cent, maximum 26 per cent); 1 patient showed no change (No. 3). The functional residual capacity increased by 10 per cent or more (maximum 132 per cent, minimum 10 per cent) in 8 patients and showed a change of less than 10 per cent in the other 3.

The *mixing index* increased to an abnormally high value (3.23 per cent) in 1 patient; this index had been normal preoperatively.

As previously noted, the ventilation at rest fell in 5 of the 11 patients; all of these had tuberculosis. With this single exception, no remarkable differences in tests of bilateral function were noted between the pre- to postoperative changes in the tuberculous and nontuberculous groups. With respect to bronchospirometry, however, inspection of Table II shows that the greatest improvement of the affected lung was noted in patients in the tuberculosis group. It is likely that this is attributable to the fact that these patients showed the poorest preoperative function.

Summary: Participation of the affected lung in ventilation at rest was increased by decortication. This was a more consistent finding than improved

*Percentages were computed by dividing the pre- to postoperative change by the preoperative value.

maximum breathing capacity and occurred independently of the latter. The residual volume and the functional residual capacity usually increased, this change occurring more frequently than improvement of the vital capacity. The proportion of the vital capacity contributed by the affected lung usually rose significantly. With one exception, intrapulmonary mixing was not adversely affected. Improvement of unilateral ventilation and volume was most conspicuous in patients with the severest preoperative deficit.

3. Postoperative Status.—Ventilation at rest was normal (below 5.0 L./minute/square meter body surface area) in 9 patients. Participation of the affected side, however, remained low in all patients except two (No. 4 and No. 6). In 9, the abnormality was such that the right lung contributed less than 50 per cent when it was the site of disease and the left lung less than 40 per cent when the left side was affected. These values had been below these levels in 8 of the 9 patients with preoperative studies. The *maximum breathing capacity* was less than 90 per cent of the predicted value in 5 of the 11 patients and less than 80 per cent in 3; it was over 90 per cent of predicted in 6.

Lung volumes: The vital capacity remained below 80 per cent of the predicted value in 6 of the 11 patients and was 90 per cent or more of predicted in three instances. The total lung capacity was less frequently so low, values below 80 per cent of those predicted being found in 3 patients. The residual volume was usually normal; in only 2 patients was a figure exceeding 150 per cent of predicted recorded. The ratio of the residual volume to the total lung capacity exceeded 30 per cent in 6 patients. In 5 of these, this ratio had been normal preoperatively. The affected lung of 10 patients remained grossly abnormal with respect to its contribution to the vital capacity (less than 41 per cent on the right in patients with right-sided involvement and less than 30 per cent on the left when this was the affected side). No patient showed a normal distribution of the vital capacity postoperatively.

All patients except 1 (No. 6) had a normal *mixing index* postoperatively.

Summary: Abnormalities of ventilation and vital capacity were the rule rather than the exception in patients studied postoperatively. These were detected more frequently by unilateral measurements than by the bilateral techniques. The residual volume and the index of intrapulmonary mixing were usually normal; the vital capacity was usually low. Comparison of tuberculous and nontuberculous groups indicated no striking differences with respect to respiratory status.

Studies of the Unilateral Total Lung Capacity (Table III)

Two patients (No. 3 and No. 8) had acceptable pre- and postoperative studies of the unilateral total lung capacity and a third (No. 9) had a satisfactory postoperative study only. Patient 8 (Fig. 3) showed a good postoperative result, that is, his vital capacity increased from 19 to 33 per cent on the side of the operation and the oxygen consumption from 13 to 24 per cent. Correspondingly, the functional residual capacity of the right lung increased 184 per cent and the residual volume 166 per cent of the preoperative value. Twenty-six per cent of the functional residual capacity and 29 per cent of

TABLE III. PRE- AND POSTOPERATIVE UNILATERAL AND BILATERAL TOTAL LUNG CAPACITIES IN 3 PATIENTS TREATED BY PULMONARY DECORTICATION

		PATIENT NO. 9		PATIENT NO. 8		PATIENT NO. 3	
		PREOP.	POSTOP.	PREOP.	POSTOP.	PREOP.	POSTOP.
Vital Capacity	Rt., c.c.	3033	2665	410	760	2492	2386
	Lt., c.c.	533	1089	1800	1560	721	685
	Sum, c.c.	3566	3754	2210	2320	3213	3071
	Bilat., c.c.	4115	4180	3310	3415	3331	3005
	Rt., %	85	71	19	33	78	78
	Lt., %	15	29	81	67	22	22
Residual Volume	Rt., c.c.	748	603	455	755	735	847
	Lt., c.c.	266	656	1115	1225	477	450
	Sum, c.c.	1014	1259	1570	1980	1212	1297
	Adj., c.c.	859					
	Bilat., c.c.	740	1321	1710	1885	1104	1360
	Rt., %	74	48	29	38	61	65
	Lt., %	26	52	71	62	39	35
Functional Residual Capacity	Rt., c.c.	1386	1225	580	1070	1310	1377
	Lt., c.c.	358	923	1685	1670	612	605
	Sum, c.c.	1744	2148	2265	2740	1922	1982
	Bilat., c.c.	1625	2121	2405	2635	1924	2070
	Rt., %	79	57	26	39	68	69
	Lt., %	21	43	74	61	32	31
Total Lung Capacity	Rt., c.c.	3781	3268	865	1515	3227	3233
	Lt., c.c.	799	1745	2915	2785	1198	1135
	Sum, c.c.	4580	5013	3780	4300	4425	4368
	Bilat., c.c.	4855	5501	5020	5300	4435	4365
	Rt., %	83	65	23	35	73	74
	Lt., %	17	35	77	65	27	26
$\left(\frac{\text{R.V.}}{\text{T.L.C.}}\right) \times 100$	Rt.	20	18	53	50	23	26
	Lt.	33	38	38	44	40	40
	Bilat.	15	24	34	36	25	31
$\left(\frac{\text{F.R.C.}}{\text{T.L.C.}}\right) \times 100$	Rt.	37	37	67	71	41	43
	Lt.	45	53	58	60	51	53
	Bilat.	33	39	48	50	43	47
Mixing Index	Rt., % N_2	0.91	0.87	6.77	2.67	cont.*	cont.*
	Lt., % N_2	1.10	1.34	1.32	1.82	2.32	4.80
	Bilat., % N_2	0.60	0.53	1.59	2.24	0.86	0.98

*Contaminated during collection. Normal index (2.5 per cent) used in computing F. R. C.

the residual volume were contributed by the right lung preoperatively; postoperatively these figures were increased to 39 and 38 per cent, respectively. The increase in the functional residual capacity of the affected side exceeded that in the inspiratory capacity, resulting in a higher ratio of the functional residual capacity to the total lung capacity postoperatively (71 as compared to 67, preoperatively). The residual volume increased in about the same proportion as the vital capacity so that the residual volume:total lung capacity ratio postoperatively was about the same as the ratio preoperatively (53 preoperatively, 50 postoperatively).

In contrast to this increase in all compartments of the lung volume in a patient with a satisfactory operative result are the figures for Patient 3 (Fig. 4) whose oxygen consumption and vital capacity suffered on the side of operation in consequence of surgery. In this patient, the functional residual capacity and

residual volume showed essentially no change as a result of the operation. Inasmuch as the inspiratory capacity and expiratory reserve also did not change, volumetric ratios remained constant. The failure of the lung to expand more fully postoperatively therefore applied to all compartments of the total lung capacity.

Patient 9 is of further interest in that gross differences in the distribution of the various volumetric compartments existed postoperatively. Thus, although only 29 per cent of the vital capacity was contributed by the left lung, the proportion of the residual volume and the functional residual capacity was 52 per cent and 43 per cent, respectively. Accordingly, on the affected side the ratio of the residual volume to the total lung capacity and of the functional residual capacity to the total lung capacity were 38 per cent and 53 per cent, respectively, as compared to 18 per cent and 37 per cent contralaterally.

Gas Exchange (Table IV)

A. Blood Gas Contents and Ventilation-Perfusion Relationships

1. Effect of Constricting Pleural Peel.—Oxyhemoglobin saturation of arterial blood below 94 per cent was found in only 1 of the 7 patients with preoperative determinations (No. 1, 91.9 per cent). Accordingly, none of the 3 patients with gradient studies demonstrated a substantially elevated venous admixture component at rest, the highest value being 9 per cent. The ratio of dead space volume to tidal volume was also normal in these 3 patients. There were no abnormalities in the carbon dioxide contents of arterial blood in the 7 patients with preoperative determinations. It is evident, therefore, that gross abnormalities in the blood gases or the relationship between alveolar ventilation and perfusion were not commonly found in the patients subjected to these analyses. The presence of marginal abnormalities, however, was not unusual. In Patient 11, these were significantly increased by exercise (Table IV).

2. Effect of Operation.—The saturation of arterial blood was improved in all save 1 of the 6 patients with pre- and postoperative determinations. The single exception (No. 2) showed a decrease in saturation from 97.3 to 92.1 per cent. The 1 patient (No. 1) with a low preoperative value was normal postoperatively (97.7 per cent).

3. Postoperative Status.—In each of the 7 patients with postoperative studies, the saturation of the arterial blood was in excess of 92 per cent. The 5 patients with gradient studies had venous admixture ratios of 7 per cent or less; dead space values were also normal (less than 30 per cent of tidal volume) in these five instances.

Summary: The patients studied did not show striking deficiencies in blood gas content or abnormalities in ventilation-perfusion relationships either pre- or postoperatively.

B. Diffusion

1. Unilateral Participation in Oxygen Uptake (Table II).—Preoperatively, the affected side invariably was abnormally low in its participation in oxygen

TABLE IV. PRE- AND POSTOPERATIVE GAS EXCHANGE DATA IN EIGHT PATIENTS TREATED WITH PULMONARY DECORTICATION

PATIENT NUMBER	ACTIVITY	BP–47*	$F_{I_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}$	f	R	Pa_{CO_2}	Ca_{CO_2}	$P_{A_{O_2}}$	Pa_{O_2}	Sa_{O_2}	$\dot{V}_{O_2}$	DEAD SPACE V_D TOTAL c.c.	DEAD SPACE V_D M^2 c.c.	$V_D/V_T \times 100$ (<30)†	VENOUS ADMIXTURE $\dot{Q}_{VA}/\dot{Q}_T \times 100$ (<6)†	DIFFUSING CAPACITY TOTAL (68-86)†	DIFFUSING CAPACITY M^2 (35-46)†	% O_2 UPTAKE AFFECTED SIDE
9	Preop Rest								51.57			95.9								18
	Exercise	711	.2093				.889	40	48.90	105	102	97.3					1			
	Exercise	711	.1306				.978	35	42.69	60	44	79.0	1806				1	65	32	
	Postop Rest	712	.2093	3.348	8.9	22.5	.840	44	51.36	99	84	95.0		106	52	27	7			16
	Exercise	712	.2093				.924	36	44.21	111	87	95.5					6			
	Exercise	712	.1261				1.132	33	36.96	59	42	77.0	2287				6	85	42	
11	Preop Rest	726	.2093	3.249	7.4	17.2	.770	43	49.44	98	84	94.8		120	67	28	7			7
	Exercise	726	.2093				.875	42	44.52	105	73	93.0					12			
	Exercise	726	.1279				1.058	33	35.75	62	37	70.0	1208				12	38	21	
	Postop Rest	721	.2093	3.729	6.9	17.7	.770	39	47.95	101	93	96.6		46	25	12	3			30
	Exercise	721	.2093				.812	37	34.20	106	81	94.5					8			
	Exercise	721	.1175				1.016	30	24.22	55	35	59.9	1470				8	54	30	
3	Preop Rest	713	.2093	3.487	5.8	13.7	.730	41	50.64	96	87	96.2		92	48	19	4			26
	Exercise	713	.2093				.880	41	44.14	103	87	95.5					7			
	Exercise	713	.1257				1.038	37	32.95	56	37	64.0	1758				7	65	34	
	Postop Rest	709	.2093						51.43			97.7								19
	Exercise	709	.2093				.921	46	43.01	107	86	95.0					6			
	Exercise	709	.1254				1.180	38	32.82	59	36	62.0	1626				6	54	28	
1	Preop Rest								44.77			91.9								
	Postop Rest	711	.2093	3.464	8.7	18.0	.850	43	48.29	100	93	97.7		131	68	27	3			26
6	Postop Rest	721	.2093	2.916	6.9	18.0	.820	40	50.00	104	86	95.0		108	71	28	8			24
7	Preop Rest								46.63			95.2								17
	Postop Rest	711	.2093	3.677	4.2	12.0	.850	45	50.98	97	91	96.9		72	35	23	2			40
5	Preop Rest	711	.2093	3.934	6.8	20.0	.900	40	49.99	105	85	95.7		27	16	8	9			24
2	Preop Rest								44.69			97.3								10
	Postop								49.89			92.1								36

*See text under "Methods" for explanations of abbreviations.
†Normal values.

uptake (below 40 per cent in patients with involvement on the right, below 30 per cent when the abnormality was on the left).

Seven of the 9 patients with pre- to postoperative comparisons showed increases on the affected side exceeding 10 per cent (mean 19 per cent, maximum 26 per cent, minimum 11 per cent). Oxygen uptake in 1 of the remaining 2 was not significantly changed (fall of 2 per cent, Patient 9) and the other (No. 3) suffered a reduction of 7 per cent.

Abnormally poor oxygen uptake on the side of operation persisted postoperatively in 9 of the 11 patients. In 6 of these (Nos. 1, 3, 6, 7, 8, and 10) the degree of abnormality was such that when the right lung was affected it contributed less than 40 per cent and where the left lung was affected its participation was less than 30 per cent. Two patients (No. 4 and No. 5) had a normal distribution of oxygen uptake postoperatively.

Summary: Pleural peels affected the ipsilateral lung adversely in all instances. Operation usually reduced the degree of abnormality significantly. In 9 of 11 patients, the restoration was incomplete.

2. The Maximum Diffusing Capacity (Table IV).—This measurement was performed preoperatively in 2 patients with moderate reduction of unilateral oxygen uptake (No. 3, 26 per cent—Fig. 4; No. 9, 18 per cent) and in 1 in whom this deficiency was severe (No. 11, 7 per cent—Fig. 2). In the former 2 the maximum diffusing capacity with exercise was minimally reduced (No. 3, 65; No. 9, 65), whereas in the latter this measurement revealed a considerable abnormality (No. 11, 38). The effects of operation as determined by this measurement were different in each instance. In Patient 3, whose unilateral contribution to oxygen uptake was reduced from 26 per cent preoperatively to 19 per cent postoperatively, the maximum diffusing capacity fell from 65 to 54 (Fig. 4 *B*). The unilateral contribution to oxygen uptake for the second patient (No. 9) was virtually unaffected by the operation; the maximum diffusing capacity, however, increased from 65 to 85. The third patient (No. 11) was considerably improved by operation (preoperative oxygen uptake on affected side, 7 per cent; postoperative, 30 per cent); accordingly, the maximum diffusing capacity increased from 38 to 54 (Figs. 2*B*). With respect to postoperative status, only the value for Patient 9 is normal, the other 2 being low. As is indicated in the discussion, the normal value is subject to question.

DISCUSSION

Factors Affecting Operative Results.—It is evident from comparing the effects of a pleural peel or the results of operation in selected instances that considerations other than etiology are the determinants of pre- and postoperative respiratory status. In the absence of extensive *parenchymal damage,* a lung which contributes negligibly to respiration preoperatively may show striking improvement postoperatively whether it be incarcerated by a tuberculous or a nontuberculous process (see Patients 2, Fig. 1, and 11, Fig. 2).

To the extent that the decorticated lung has been destroyed by disease, the postoperative status is understandably jeopardized (Patients 6 and 8, Fig. 3). Inasmuch as such irreversible damage is more commonly associated with

tuberculous pleural involvement than it is with the other conditions for which decortication is performed, results in tuberculous patients unselected for the absence of parenchymal involvement can be expected to be relatively poor.[5] It should be observed, however, that the limitation in recovery for patients receiving early treatment is imposed by the presence of pulmonary pathology rather than by the etiology of the pleural peel. Although this point has been clearly made by studies of patients other than ours,[3] previous implications to the contrary[4, 5] may justify its re-emphasis.

The *duration of incarceration* is another of the factors which affect the degree of functional improvement.[4] The limited change found in Patient 8 (Fig. 3), contrasting with the conspicuous restoration in Patients 5 and 11 (Fig. 2), is probably partly attributable to the length of time during which the affected lung's activity was restricted. The adverse effect of time is perhaps less surprising, however, than is the fact that improvement of the magnitude recorded is possible after seven years of restriction (Patient 8, Fig. 3). Indeed, even longer periods have been shown to be compatible with significant recovery.[3] It should be pointed out that preoperative appraisal is particularly important in these patients, for in its absence the degree of postoperative abnormality might obscure the value of operation.

The adverse effect of *operative complications* is illustrated by a comparison of the figures for Patients 1 and 2 (Table II) both of whom had a nontuberculous pleural membrane on the left. Inadvertent left phrenic nerve paralysis and a postoperative empyema in the former doubtless account for the relatively low postoperative values recorded. Similarly, the postoperative bronchospirometric differences between Patients 10 and 11, both of whom had comparable preoperative deficits due to tuberculous empyema, are in all likelihood attributable to a postoperative bronchopleural fistula in the former.

Among the additional considerations which must be weighed in anticipating the functional change as well as the postoperative result is the patient's *preoperative status.* Obviously a patient with normal function preoperatively cannot be expected to improve and, correspondingly, one with extremely poor function can hardly be adversely affected. Among the 11 patients, 7 were comparable with respect to age, sex, minimal or no parenchymal involvement, duration of disease (less than one year), and absence of serious postoperative complication. Among these, improvement in vital capacity or maximum breathing capacity was usually not found unless these modalities were depressed below 70 per cent of normal preoperatively.

Selected Observations.—Among the most constant effects of pulmonary decortication in these 11 patients was an increase in residual volume, a change which could be attributed to the removal of a noncommunicating intrathoracic mass and to the release of retracted parietes. Associated roentgenographic findings were the elimination of density between the lung and thoracic wall and the widening of the intercostal spaces which was frequently seen postoperatively. This increase in residual volume, either absolute or relative to the total lung capacity, should not be identified with "overdistention" and construed as

detrimental to function. Patient 7, for example, demonstrated an increase in oxygen uptake on the affected side from 17 per cent preoperatively to 40 per cent postoperatively although his residual volume almost tripled and the volumetric ratio became abnormal (40 per cent). So long as it is not assumed that the increase in residual volume is out of proportion to the additional number of inflated alveoli, there is reason to interpret the change as favorable rather than the opposite.

The functional residual capacity was also commonly augmented by operation, an increase exceeding 200 c.c. having occurred in 7 of the 11 patients. The reasons for this increase parallel those cited for the changes in residual volume.

In reconstructing the corollaries of these volumetric increases in a patient such as No. 11 (Table II, Fig. 2*B*), it is reasonable to assume that a portion, if not most, of the additional air contained by the lung fills alveoli which were previously collapsed. In the present study and in that of Carroll,[4] the figures for physiologic dead space and for venous admixture both pre- and postoperatively suggest that normal relationships between ventilation and perfusion are approximated in compressed as well as in re-expanded parenchyma; areas which are unventilated preoperatively tend also to be unperfused and those that are ventilated are correspondingly perfused. As alveoli open postoperatively, the restoration of their ventilation tends to be matched by perfusion of their capillaries with blood. Expansion of the alveolar-capillary bed is the structural result, the functional counterparts being a relative increase in the contribution of the affected lung to oxygen uptake and an augmented diffusing capacity.

Although these latter two indices differ in precision and to some extent in implication, they are nevertheless both functions of the expansiveness of the alveolar-capillary bed.[13] Accordingly, a change in one was associated in 2 patients (No. 3, Fig. 4*B* and No. 11, Fig. 2*B*) with a change of similar sign in the other.

In the third patient subjected to both analyses pre- and postoperatively, unilateral uptake of oxygen was not significantly affected by surgery (preop. 18 per cent, postop. 16 per cent). Diffusing capacity, however, increased from 65 preoperatively to 85 postoperatively. A difference of this magnitude might be explained by summating the maximum errors of the analyses required for measuring the diffusing capacity.[12] Indeed, the fact that the postoperative figure is normal, although the participation of the left lung in oxygen uptake is so low, suggests that estimation of the diffusing capacity, bronchospirometric determinations, or both, were in error. An alternative explanation, assuming the reliability of both figures, is that the exercise required for the maximum diffusing capacity determination brought out properties of the lung not detectable in the "resting" state. Exercise is known to result in expansion of the diffusing surface.[12] It is conceivable that exercise increased the effective diffusing surface postoperatively in spite of the fact that the relative dimensions on the right and left at rest remained unaltered.

Despite improvement, no patient was fully restored to normal by operation. The short postoperative interval elapsing before the second study probably accounts in part for this limited recovery. Patients studied within three months

following even a minimal resection commonly show a loss in vital capacity and maximum breathing capacity amounting to 12 per cent of their preoperative value.[17] Wright and his associates[1] and Patton and his co-workers[2] have shown that unilateral return of function following decortication is protracted, in some instances extending over a period exceeding one year. With these considerations in mind, it is evident that the extent of improvement in the present patients was probably less than may be expected ultimately. By the same token, the minimally adverse effects on some tests in Patients 3, 4, 6, and 9 would possibly not have been found after a longer convalescence. In no instance was there evidence, as reported in some patients with extensive parenchymal damage,[1] that the respiratory status postoperatively included gross abnormalities which had not been present preoperatively.

Attention has been drawn[4] to the number of patients in whom contribution of the decorticated lung to oxygen consumption is less than that to ventilation and a pathologic basis for this finding in tuberculosis has been suggested. This disproportion was found in 5 of the 11 patients. Each of these had either parenchymal damage (No. 6, No. 8), a postoperative complication (No. 1), or a poor functional result in terms of unilateral oxygen uptake (No. 3 and No. 9). In none of the other 6 patients, 4 of whom had tuberculous pleural disease (Nos. 5, 7, 10, and 11), did this finding prevail. When parenchymal damage was minimal or absent and when operation was early and uncomplicated, therefore, proportionate participation in ventilation and oxygen consumption was the rule rather than the exception. If one uses oxygen uptake as a criterion of perfusion, it is apparent that this generalization follows from the fact that the postoperative values for ventilation-perfusion relationships fell within normal limits.

SUMMARY

Eleven patients requiring pleural decortication of either a tuberculous or a nontuberculous pleural peel were evaluated from a respiratory point of view both pre- and postoperatively. The tests pertained to unilateral and bilateral ventilation and total lung volumes, intrapulmonary mixing of respiratory gases, ventilation-perfusion relationships, and relative dimensions of the diffusing surface (maximum diffusing capacity).

The preoperative deficit usually consisted of impaired ventilation, diminished lung volumes, and a reduction in the dimensions of the alveolar capillary bed. Defects in the mixing of gases within the lung and in the relationship between ventilation and perfusion were uncommon.

Operation was usually followed by improved ventilation, increased lung volumes, and restoration of alveolar-capillary units. Etiology per se did not affect the magnitude of these changes. Duration of disease, parenchymal involvement, postoperative complications, and the degree of preoperative functional impairment were factors contributing to the extent of recovery. Protracted disease did not preclude improvement.

Postoperatively, no patient was normal with respect to all tests, possibly because the convalescence prior to re-evaluation was brief. No gross deficit occurred as the direct result of surgery.

Consistent with the essentially mechanical nature of the impairment imposed on the lung by pleural envelopment, the physiologic abnormalities produced were reversible to varying degrees by surgical removal of the confining structures.

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COMPLICATIONS OF FIRST RIB FRACTURE, INCLUDING ONE CASE EACH OF TRACHEOESOPHAGEAL FISTULA AND AORTIC ARCH ANEURYSM

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SURVEY OF LITERATURE: INCIDENCE AND COMPLICATIONS

FRACTURE of the first rib has become an increasingly frequent injury since the advent of the modern automative age. Despite its sturdy structure and relatively protected situation, the first rib is vulnerable to sufficient degrees of indirect violence such as that supplied by the "steering wheel" chest injury, or from direct violence of various types. According to Johnston,[1] who reported an early case of first rib fracture complicated by lung abscess, these principles were emphasized more than sixty years ago by Lane,[2] who postulated three mechanisms by which the first ribs were liable to fracture: (1) indirect violence transmitted through the clavicle, (2) direct violence from force applied from behind, and (3) indirect force transmitted through the sternal manubrium.

The earliest available record of traumatic first rib fracture was that by Jones,[3] 1869, whose patient was injured in a street fight. Apparently the first recorded case due to automobile accident was that of Codd,[4] in 1916. Neither of these patients had significant associated injury or complication.

Several recent series attest the increasing frequency of first rib fracture. Hinton and Steiner,[5] in 1940, described it in 14 of 393 right, and 8 of 414 left fractured ribs. Knoepp,[6] 1941, found 16 fractures of the right first rib, and 15 of the left, in a total of 386 cases of rib fracture. Powell[7] discovered 25 cases in the British Army during a nine-month period in 1950, not due to combat injuries. Huber,[8] however, was able to find only 26 cases in the world literature prior to 1934, to which he added 4 personal cases. Huber emphasized the difficulty of diagnosis of the uncomplicated case by x-ray, especially in instances in which other fractured ribs, more readily recognized, might explain the symptoms presented. That such a fracture may occasionally heal unrecognized is indicated in the reports of Cohen,[9] and Alderson,[10] who discovered healed, previously undiagnosed, isolated fractures of a first rib in approximately 0.1 per cent of routine chest x-ray in a combined series of more than 80,000 young military personnel. In 10 of Alderson's 73 cases, the fracture had been bilateral.

A variety of complications have been attributed to fractures of the first rib, but in most instances these have been the usual complications accompanying

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the fracture of any rib. Breslin,[11] in 1937, listed these complications of first rib fracture: (1) abscess formation, above or below the clavicle, (2) rupture of the apex of the lung, (3) empyema, (4) pleurisy, (5) hemorrhage, and (6) nerve symptoms, immediate, or delayed, due to pressure of callus. Ostrowski[12] described a ruptured subclavian artery resulting from fracture of the right first rib. Paralysis of the brachial plexus accompanying such injury has been described by Milligan and Ford,[13] and by Chavany, LeRoy, and Lobel.[14] Horner's syndrome caused by fracture of first rib was reported by Rebhorn,[15] and by Kulowski and Ryan.[16] Massive cervical subcutaneous emphysema occurred in 1 case of Huber's series.[8] Zimmerman[17] described a hematoma occupying the superior and middle mediastina following severe lateral chest compression which had resulted in fracture of the first and second ribs bilaterally, the left clavicle and right scapula. The hematoma resorbed spontaneously without sequelae.

ANALYSIS OF EIGHT YEARS' EXPERIENCE WITH REPORT OF TWO CASES

The occurrence of severe mediastinal complications in 2 patients suffering first rib fracture prompted a survey of our experience with this entity at this large veterans hospital. From Jan. 1, 1947, through Dec. 31, 1954, 170 patients were hospitalized with a diagnosis of fractured ribs, many associated with other injuries. Of this number, 17 (10 per cent) had fractures of one or both first ribs, isolated, or in addition to other rib fractures. These cases are briefly summarized in Table I. One patient, whose fracture was produced by a shotgun wound, has been omitted from the series. All the remainder had closed chest trauma.

It is readily apparent that in 2 patients (Case 10 and Case 16, Table I) there were significant complications involving mediastinal structures which could reasonably be attributed to the mechanisms responsible for fracture of the upper ribs. These cases will be considered individually.

As would be expected, the incidence of brachial plexus injury in this group (3 cases) was much higher than in the rib fracture series at large, especially since there was ipsilateral fracture of the clavicle in one of these.

It is interesting that there were 15 cases of second rib fracture, including one of bilateral occurrence, other than those accompanying fracture of a first rib, and of this group only one, which was associated with an ipsilateral clavicular fracture, showed evidence of brachial plexus injury. There were no mediastinal complications in this group, or in the remainder of the rib fracture series, the complications being confined to the usual effects of pleural puncture by the bone fragments: pneumothorax, hemothorax, subcutaneous emphysema, pneumonitis, and empyema, in order of frequency named.

Case 1 (Table I) was unusual in that a Horner's syndrome occurred on the right, where no rib cephalad to the fourth was fractured, while there was no evidence of associated lesion in the vicinity of the fractured left first rib. The other patient in the series exhibiting injury to the stellate ganglion (Case 12, Table I) had suffered fracture of the right first and second ribs in addition to the right clavicle.

TABLE I. CASES WITH FIRST RIB FRACTURE*

CASE NUMBER	PATIENT	AGE	HOW INJURED	RIBS FRACTURED	ASSOCIATED INJURIES	COMPLICATIONS	TREATMENT	REMARKS
1	R. N. U.	25	Auto accident	L 1 R 4-8	Fract. rt. scapula	Horner's syndrome, right	Symptomatic	No sequelae; 3-year follow-up
2	L. F. G.	37	Auto accident	L 2-4 R 1-5	Fract. pelvis	Right hemothorax; Right brachial plexus injury (Ulnar Dist.); Emphysema trunk and neck	Thoracenteses; Symptomatic	Well after 4 months; nerve injury transitory
3	K. B. W.	22	Auto accident	L 1	--	--	None required	No follow-up
4	F. R.	34	Auto accident	L 1, 2	Fract. facial bones; Fract. left scapula; Cerebral concussion	--	Orthopedic	5-year follow-up; chest negative
5	L. C.	26	Auto accident	R 1, 2, 4	Laceration, face	Contusion lung (hemoptysis); Right brachial plexus inj.	Symptomatic	Well after 3 weeks
6	L. W.	62	Auto accident	L 1, 5-9 R 1-10	Fract. vert. T 12, L 1-4; Fract. skull; Laceration, liver	Hemothorax, bilateral	--	Expired on admission
7	R. L. M.	44	Auto accident	R 1	Fract. femur, tibia	--	Orthopedic	Well after 3 months
8	T. C. M.	38	Auto accident	L 1, 3, 5 R 2-5	Fract. radius	Right pneumothorax (partial)	--	Refused treatment; chest neg. 1 year later
9	J. H.	57	No history	L 1 R 1	--	Bilat. obst. subclavian veins by callus	--	Admitted in heart failure; fractures discovered at autopsy

10	C. D. T.	24	Auto accident	L 1	--	Diverticulum esophagus with tracheo-esoph. fistula	Repair of divert. and fistula	3-month follow-up; no recurrence
11	J. R.	29	Auto accident	L 1-3 R 5-7	Fract. humerus, bilat.; Rt. sternoclavic. separation; Cerebral concussion	--	Orthopedic	2-year follow-up; chest negative
12	C. L. K.	21	Auto accident	L 2 R 1, 2	Fract. rt. clavicle	Rt. brachial plexus injury; Horner's syndrome, right	Symptomatic	Well after 1 month; nerve lesions transitory
13	W. H. B.	35	Auto accident	R 1	Fract. acetabulum; Compound fract. tibia	--	Symptomatic	6-month follow-up; chest negative
14	H. H. W.	30	Crushed by lumber stacker	R 1-8	--	Hemothorax; Pneumothorax	Thoracenteses; Transfusions	2-year follow-up; chest negative
15	J. A. R.	42	Auto accident	R 1	Fract. vert. C 2, 6, 7	--	Orthopedic	2-year follow-up; chest neg.; no neurological sequelae
16	H. F. M.	24	Auto accident	L 1, 2	Fract. tibia and fibula	Aneurysm, aortic arch	Aneurysm wrapped with reactive polyethylene	6-month follow-up; aneurysm slightly smaller; no referable complaints

*All patients are men. Those with two initials are Negro.

The unusual effect of fracture healing in Case 9 (Table I) is thought to be of sufficient interest to warrant brief description. A 57-year-old Negro man was hospitalized in a state of cardiac failure. He had a long history of syphilitic and hypertensive cardiovascular disease, with multiple admissions to this institution. No history of trauma was given. An unusual feature was marked edema of both upper arms, which was out of proportion to ankle edema and other manifestations of right heart failure. The patient followed a rapidly deteriorating course, and died on the eighth hospital day. At autopsy, recent fractures of the first ribs bilaterally, 5 cm. from the costosternal junctions, were found. Callus about the healing fractures measured 4 cm. in diameter, compressing the subclavian veins against the clavicles at those points. This, in the pathologist's opinion, was sufficient to produce the marked edema of the upper arms.

CASE REPORT

The patient, C. D. T. (Case 10, Table I), was a 24-year-old white man who was first admitted to the Veterans Administration Hospital, Jackson, Miss. on July 4, 1952, one week following an automobile accident in which he suffered a "steering wheel injury" to the chest. He had no significant complaints until four days following the accident, when he developed a sore throat, had difficulty in swallowing, and regurgitated a piece of meat eaten the previous day. There was evidence of acute pharyngitis, which responded to antibiotic therapy. The chest was clear, and x-rays reportedly negative for rib fracture. His symptoms improved sufficiently so that he was discharged on July 23, 1952.

One month after discharge the patient returned to the Outpatient Department complaining of an intermittent dry cough. X-ray on that date revealed a healing fracture of the left first rib. Examination was otherwise negative.

He continued to cough intermittently, and noted that swallowing liquids frequently resulted in coughing and gagging, while he had no difficulty in swallowing solid foods. The sputum became purulent, occasionally blood streaked, and he developed a low-grade fever. He was readmitted to the medical service on Nov. 7, 1952, with the diagnosis of lung abscess, left upper lobe, thought to be due to material aspirated at the time of the injury, or during the episode of pharyngitis.

The abscess was evacuated spontaneously, and entirely disappeared on conservative management during one month of hospitalization. Bronchoscopy during this admission revealed only congestion of the mucosa of the left main bronchus.

Ten days following discharge, the patient was again admitted to the medical service, with evidence of pneumonitis, lower lobe, right lung. Again there was rapid response to antibiotics. However, in view of the recurring respiratory difficulties, and the continued complaint of cough induced by swallowing liquids, surgical consultation was obtained.

An esophagram on Jan. 2, 1953, revealed an anterior esophageal diverticulum of the pulsion type at the level of the fourth thoracic vertebra (Fig. 1). There was no sign of barium entering the trachea, however it was noted fluoroscopically that the filled diverticulum impinged upon the trachea, producing coughing and gagging. Bronchoscopy was repeated, revealing an erythematous papule, 6 mm. in diameter, on the posterior tracheal wall just above the bifurcation. A droplet of mucus exuded from the center of this lesion during observation, and was assumed to have passed through a fistula originating from the esophageal diverticulum. No additional information was obtained from esophagoscopy.

Thoracotomy was performed on Feb. 4, 1953, through the right fourth intercostal space. There was a diverticulum of the esophagus, approximately 2 cm. in diameter, situated 4 cm. above the level of the azygos vein. It arose from the anterior surface, and was intimately attached to the posterior wall of the trachea (Fig. 2*A*). There was considerable fibrosis and edema of tissue surrounding the diverticulum. The diverticulum, which measured 4 cm. in length, was freed of surrounding tissues and divided at its mid-point between two small

bronchial clamps. Each stump was closed with two rows of interrupted No. 3-0 silk mattress sutures, so spaced as to obliterate the diverticulum, and thus the fistula, at both ends (Fig. 2*B*). The thorax was closed in routine fashion, with water-seal drainage.

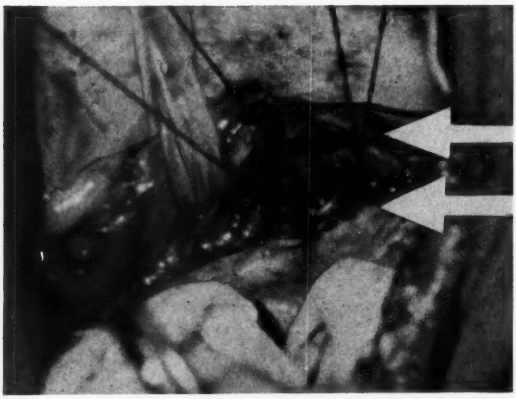
The postoperative course was uneventful. The patient was fed by gastric tube for five days, and was allowed a soft diet on the tenth day. He was discharged on Feb. 16, 1953, with no complaint. In answer to a letter on April 27, 1953, the patient stated that he had remained symptom free. Following this, he was unfortunately lost to follow-up.

Fig. 1.—Case 10, Table I. Esophagram which reveals a pulsion diverticulum on the anterior wall of the esophagus. No barium entered the diverticulotracheal fistula.

To summarize, an esophageal diverticulum, with fistulization into the trachea, was diagnosed and repaired six months following an automobile accident which had resulted in fracture of the left first rib. Symptoms present during the intervening period strongly suggest that the diverticulum, as well as the tracheoesophageal fistula, was traumatically incurred. It is possible, however, that an asymptomatic congenital diverticulum had existed previously, and that traumatic fistulization occurred between the trachea and this weak point of the esophageal wall.

Comment.—An excellent review of tracheoesophageal fistula resulting from closed chest trauma has been recently presented by Volk, Storey, and Marragoni,[18] who found 7 previous cases,[19-25] and reported a personal case which was unique in that it involved the cervical trachea and esophagus, and was

A.



B.

Fig. 2, *A* and *B*.—Case 10, Table I. *A*, Diverticulum of anterior esophageal wall, the fundus intimately adherent to the posterior tracheal wall, where a small traumatic fistula had developed. The esophagus is retracted posteriorly by a rubber drain. The arrow points to the fistula which is retracted by a linen tape. *B*, The diverticulum divided, each stump obliterated with double rows of interrupted silk sutures. Arrows indicate suture lines.

the first reported case due to blast injury. In none of these instances did fracture of a first rib occur, however, Piquet, Muller, and Marchand[20] described fracture of left ribs 3, 4, and 5, and the patient of Stephens and Ferrier[23] suffered a fracture of the left scapula.

Six of these patients[18, 21-25] were treated by definitive surgery with good results. Five authors[21-25] used the right thoracotomy approach originally em-

ployed by Adams and Mabley.[21] Volk, Storey, and Marragoni[18] used a left anterior cervical approach to repair the fistula they reported, which lay at the level of the thyroid isthmus.

In the case of Piquet, Muller, and Marchand,[20] there was an esophageal diverticulum at the site of the fistula, similar to the situation just described. The diverticulum, however, was thought to have been pre-existing, rather than a product of the trauma which was responsible for the fistula. No other such combination has been reported, although Jenkinson and Bate,[26] and Coleman and Bunch[27] reported fistulas between esophageal diverticula and the tracheobronchial tree from causes other than trauma.

Apparently, then, this case represents the ninth reported instance of *tracheoesophageal fistula* resulting from closed trauma to the chest, and the first to be associated with a fracture of a first rib. It is the seventh such fistula to be successfully repaired by direct division and suture.

CASE REPORT

The patient, H. F. M. (Case 16, Table I), was a 24-year-old white man who was admitted to the Veterans Administration Hospital, Jackson, Miss. in October, 1952, following an automobile accident in which he suffered simple fracture of the right tibia and fibula, in addition to fractures of the left first and second ribs. Chest x-ray revealed a widening of the superior mediastinum in the posteroanterior view (Fig. 3), interpreted as hematoma and/or mediastinitis, secondary to the chest trauma. There were no referable complaints, or signs of mediastinal involvement. The extremity fractures were treated on the orthopedic service with open reduction, the hospital course being complicated only by the development of a mild left pneumonitis with pleural effusion, which responded to conservative management. On subsequent orthopedic observations in December, 1952, March, 1953, and May, 1953, there was no symptom or sign referable to the chest, the mediastinal shadow remaining unchanged by x-ray.

In December, 1954, the patient applied for re-enlistment in the Marine Corps. Chest x-ray revealed a mass in the vicinity of the aortic arch. He was disqualified for enlistment, and hospitalized for appropriate studies to determine the nature of the lesion. There had been no complaints referable to the chest or cardiovascular system. The patient had been employed as a ward attendant in a mental institution for six months prior to admission, with no limitation of activity.

Past history, in addition to the injuries described, included multiple skull fractures incurred in a fight in November, 1951, following which the patient had developed grand mal epilepsy. Fractures of maxilla and ilium were sustained in an automobile accident in April, 1952. Following each injury, chest x-rays at this institution had been normal. There had been no epileptic seizure for eight months prior to the last admission.

On admission, Dec. 28, 1954, there were no abnormal physical signs. Blood pressure was 110/72, both arms. The chest was clear, with no palpable thrill, bruit, or murmurs. Chest x-ray revealed a mass which appeared to project into the left lung field above the hilar region, with a suggestion of fine calcium deposits in its periphery. On fluoroscopy, the mass could not be dissociated from the aortic shadow, and it displayed an expansile type of pulsation. An angiocardiogram on Jan. 3, 1955, confirmed the impression of aneurysm of the descending portion of the aortic arch (Fig. 4, *A* and *B*). Routine laboratory studies, including sputum examination and tuberculin tests, were negative. Bronchoscopy was normal but for a suggestion of increased carinal pulsation. Left scalene fat pad biopsy, requested by the chest therapy board, was negative for neoplasm.

Thoracotomy was performed on Jan. 11, 1955, through a sternal splitting incision extending into the left third intercostal space. An aneurysm measuring 6 by 8 cm. on its predominant

surface, which extended anteriorly and to the left, was found to involve the distal half of the aortic arch (Fig. 5*A*). It was more fusiform than saccular, involving more than one half of the circumference of the aorta. The left subclavian artery arose from the proximal portion of the aneurysm, and the left vagus and phrenic nerves were embedded along its lateral wall, which was partially calcified.

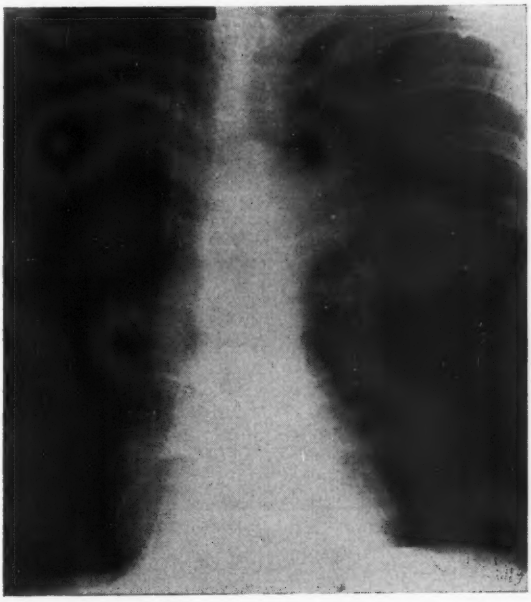
Abandoning the preoperative hope that the aneurysm would lend itself to tangential resection, it was freed sufficiently from adjacent tissues, including the vagus nerve, to allow the placing of a polyethylene sheet containing diacetyl phosphate against its entire surface.

Fig. 3.—Case 16, Table I. Posteroanterior view of chest, following automobile accident, which reveals widening of the superior mediastinum, partially obscuring the aortic arch shadow. Note fracture of left first and second ribs.

This was covered with a second sheet of nonirritating polyethylene, and sutured snugly to the mediastinal pleura about the aneurysm (Fig. 5*B*). The phrenic nerve, which was deeply embedded in the calcified portion of the adventitia, was not disturbed. The thorax was closed in routine fashion, with dependent water-seal drainage.

The postoperative course was uneventful except for two mild epileptic seizures, which responded to appropriate medication. There was persistent elevation of the left hemidiaphragm to the eighth posterior intercostal space, thought to be due to irritation of the phrenic nerve by the polyethylene.

A.

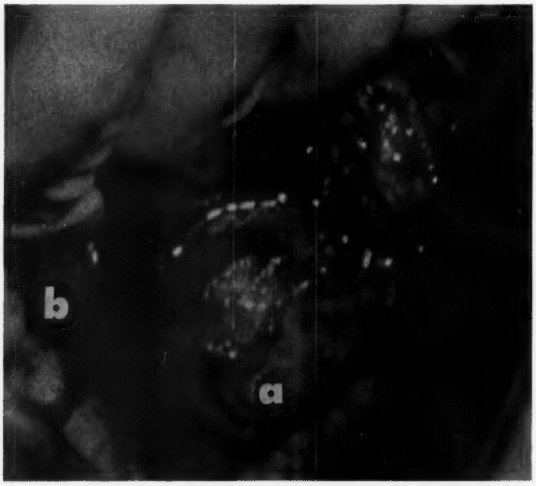


B.

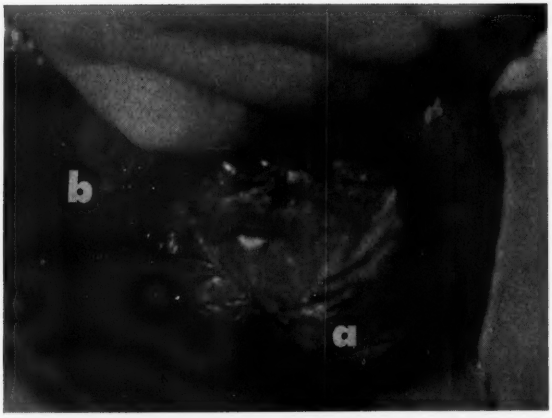
Fig. 4, *A* and *B*.—Case 16, Table I. *A*, Posteroanterior view of chest, twenty-seven months following injury, which shows mass protruding from vicinity of the aortic arch. *B*, Angiocardiogram which reveals mediastinal mass to be continuous with arch of aorta.

The patient was discharged on Feb. 18, 1955, to remain at limited activity. He was seen on April 20, 1955, at which time he had no complaints. Blood pressure was 118/76 both arms, the chest was clear. A posteroanterior chest film on that date revealed slight diminution in size of the aneurysm (Fig. 6). He was personally contacted on May 29, 1955, and again had no complaints.

To summarize, a *traumatic fusiform aneurysm* involving the distal portion of the aortic arch was diagnosed more than two years following an automobile accident which had resulted



A.



B.

Fig. 5, *A* and *B*.—Case 16, Table I. *A*, Traumatic aneurysm of thoracic aorta, involving distal half of arch. The left subclavian artery arose from the proximal portion of the aneurysm, and the left vagus and phrenic nerves were embedded along its anterior surface. Calcium plaques may be seen in the most prominent area. Aortic aneurysm is marked by "a," and descending aorta by "b." *B*, Aneurysm covered with irritative polyethylene, with outer layer of nonirritating polyethylene, both sheets sutured to mediastinal pleura about all surfaces of the aneurysm. The aortic aneurysm is marked "a," and descending aorta is just below "b."

in fracture of the left first and second ribs. Some widening of the superior mediastinum detectable by x-ray shortly following the accident, and attributed to hemorrhage and/or mediastinitis, may have been, in retrospect, an important clue to the extent of trauma to the aortic arch. The aneurysm, which was entirely asymptomatic, was covered with reactive polyethylene. On early follow-up, it has responded well to this conservative surgical attack.

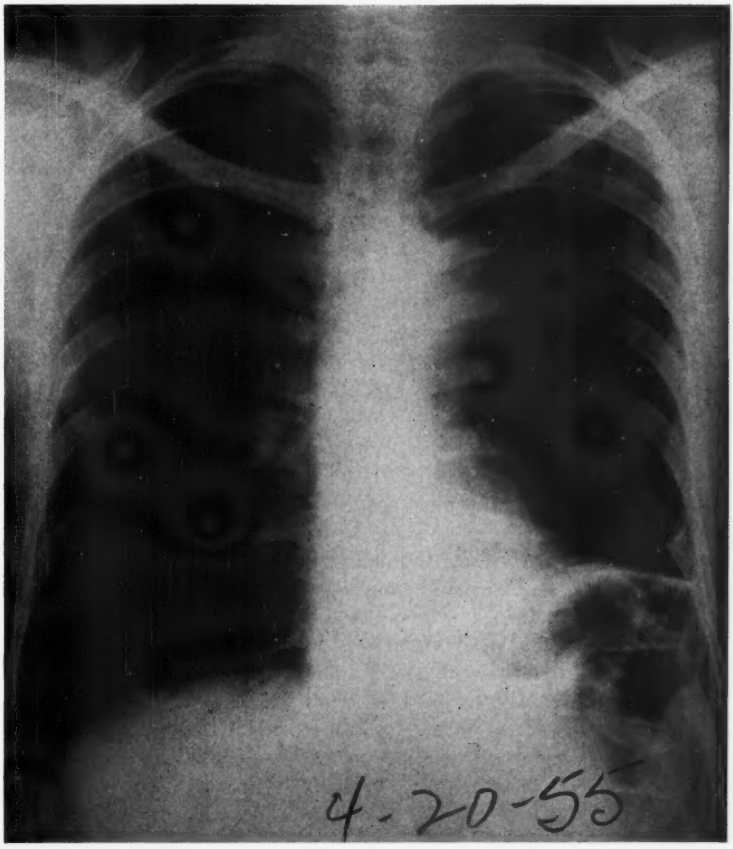


Fig. 6.—Case 16, Table I. Posteroanterior view of chest made three months after covering aortic arch aneurysm with reactive polyethylene. The mass is slightly smaller than in the preoperative film (Fig. 4*A*). Note persistent elevation of the left hemidiaphragm, apparently from irritation of phrenic nerve.

Comment.—The mechanical factors culminating in aneurysm of the thoracic aorta secondary to indirect trauma have been well conceived. Shennan[28] theorized that such aneurysms should occur at three sites: (1) just above the aortic valve, (2) just below the attachment of the ductus arteriosus, and (3) at the origin of intercostal arteries. These postulates were influenced by the work of Oppenheim,[29] who produced intimal rupture in cadavers' aortas at Shennan's sites 1 and 2 by injecting fluid at high pressure (3,000 mm. Hg). The

ruptures in the ascending aorta were predominantly transverse, while those at the ductus area were longitudinal or oblique. Oppenheim was able to collect over 100 case reports of ruptured, otherwise healthy, ascending aortas in cases of coarctation subjected to trauma.

Warfield[30] postulated that injury to the aorta and heart from sudden compression of the chest was more likely during full inspiration, when these structures would be bound between inflated lungs. He believed further that such trauma would be more exaggerated with the heart in diastole. Peery[31] stated that closure of the heart valves produces traction on the aortic wall, and offered this as an additional factor in traumatic aortic rupture. Clinically, Peery recognized incomplete aortic rupture as a first stage of dissecting aneurysm.

Recently, Rice and Witstruck[32] have outlined the play of forces involved in trauma of the sudden deceleration type, as is the case in the majority of automobile accidents. "In linear deceleration of the thorax, the central portion of the descending aorta, being the least rigidly bound, is snapped forward by the momentum of the deceleration force and the mass of the aorta's content of blood . . . the upper portion of the aorta is most rigidly fixed by the great vessels of the arch and the ligament arteriosum. This portion decelerates at the same rate as the whole body . . . the descending aorta decelerates at a different rate. This difference constitutes the force which is concentrated at the point of maximum fixation."

Strassman[33] found 61 isolated traumatic ruptures of the aorta in a series of 7,000 autopsies. Fifty-eight of these involved the thoracic aorta, 38 of which were just distal to the ligamentum arteriosum, where the aorta is normally narrowed, and fixed by this ligament.

Traumatic aneurysm of the thoracic aorta has long been a well-recognized entity, yet the number of reported cases has been comparatively small, probably because of the high incidence of immediate fatality in aortic rupture. According to Kahn and Kahn,[34] the lesion was mentioned by Versalius more than 300 years ago. Of 167 cases of aortic aneurysm reported by Crisp[35] in 1847, 6 were of traumatic etiology. In 1870 Albutt[36] reported 2 cases of traumatic aneurysm of the ascending aorta, and Moxon[37] described a similar case. In each instance the diagnosis was made on the basis of symptoms and physical signs following severe chest injury.

Heller,[38] in 1903, described a saccular aneurysm of the ascending aorta following a closed injury of the chest. Gomez[39] (1927), Hübener[40] (1928), and Kaufman[41] (1929), each reported a single similar case. Shennan[28] described a 57-year-old man, struck by a bicycle, who suffered a fracture of the left clavicle and first rib complicated by an aortic aneurysm at the level of the tracheal bifurcation, which ruptured spontaneously into the esophagus eight weeks postinjury. Samson,[42] in 1931, reported a case of a dissecting aneurysm of the descending aorta five years following an automobile accident.

In more recent reports, Leonard[43] described a 60-year-old man with a "steering wheel injury" fracturing the sternal manubrium, and producing a dissecting aortic aneurysm which ruptured into the left pleural cavity on the sixteenth day postinjury. Stryker[44] reported the case of an 18-year-old girl

who died of subacute bacterial endocarditis five months following an automobile accident. At autopsy two separate aneurysms were discovered in the ascending aorta. The larger of the two, situated on the posterior wall, was saccular in type. Stryker also encountered a man who survived five days with a 3 cm. intimal laceration in the descending aorta, which, at autopsy, had dissected 1 cm. in all directions. His third case, a man who died in three hours following an accident in which he suffered a transverse rent in the ascending aorta, producing pericardial tamponade, hardly seems to fit the criteria for an aneurysm.

The first report of a successful, planned surgical procedure directed at the correction of a traumatic aneurysm of the aortic arch was that of Weisel, Huttner, and Becher[45] (1951). Their patient was a 25-year-old man first seen four years following an automobile accident in which he suffered fractures of multiple bones, including the left clavicle. Medical consultation relative to complaints of mild hypertension, which developed one year following the injury, led to the discovery of a fusiform aneurysm of the descending portion of the aortic arch, 5 cm. in diameter, arising just distal to the origin of the left subclavian artery. Being unable to resect the aneurysm tangentially, they elected to wrap it with reactive cellophane, following the technique applied to syphilitic aneurysms by Poppe and de Oliveira.[46] Ten months following operation the patient had no complaint, and x-ray revealed a slight decrease in size of the aneurysmal shadow.

A similar procedure was performed by Hollingsworth, Johnston, and McCooey[47] (1952) on a 27-year-old man, five months following an automobile accident in which he had suffered contusion of the chest. The aneurysm, situated 5 cm. below the origin of the left subclavian artery, was recognized three months following the injury. In reviewing serial radiographs, however, the authors were able to trace, in retrospect, the development of the lesion which is well illustrated in their excellent essay. Two years following cellophane wrapping, the aneurysm shadow was unchanged by x-ray. The patient, however, exhibited some pain associated with heavy labor, which was thought to reflect possibly some extension of the process. These authors described 2 additional patients with almost identical lesions, who had exploratory operations eighteen months and twelve months, respectively, following automobile accidents. No treatment was accorded the aneurysm in either case. The former was seen before reactive polyethylene became available, while in the latter, the wall of the aneurysm was considered too thin for safe dissection in its vicinity. In a fourth patient, suffering a fractured sternum in a "steering wheel injury," aneurysm of the aortic arch was diagnosed by x-ray two months following injury, after a widening of the mediastinum was detected originally. The authors did not advise surgery in this case, for reasons not explained.

The first traumatic aneurysm of the aortic arch to be successfully resected with preservation of aortic continuity was reported by Bahnson,[48] as one of a series of eight saccular aneurysms resected in this manner. The remainder of the series were syphilitic aneurysms. Bahnson's patient, a 49-year-old woman, developed a large aneurysm of the terminal arch, involving the origin of the

left subclavian artery as a result of an automobile accident in which she suffered fracture of the third ribs bilaterally, and the body of the first lumbar vertebra. The aneurysm was wrapped with reactive cellophane nine months following injury. Symptoms recurred one year postoperatively, accompanied by clinical and x-ray evidence of enlargement of the aortic shadow. The lesion was excised tangentially fifteen months following the first procedure, two years following injury, with good result.

Resection of traumatic aneurysms of the aortic arch and replacement by homografts have been successfully accomplished on two occasions. Stranahan, Alley, Sewell, and Kausel[49] report the case of a 25-year-old Negro man with a "classical traumatic aneurysm of the descending aorta" discovered by routine x-ray five years following an automobile accident of the steering wheel type. Multiple fractures of the skull and extremities, and contusions of chest and abdomen had occurred, though no fractures of rib, sternum, or clavicle were found.

Being unable to excise the aneurysm tangentially, which arose just below the left subclavian artery and encircled three-fourths of the aorta's circumference, Stranahan and his team excluded the distal aortic arch by means of an ingeniously devised shunt of Tygon, polyethylene, and silicone glass, which delivered blood from the subclavian artery into the aorta distal to the aneurysm. The aortic segment containing the aneurysm was resected, and replaced with an 8 cm. length of homologous freeze-dried aorta. On five-month follow-up the patient was doing well. These authors had previously employed a similar device in resecting a massive syphilitic aneurysm involving the entire thoracic aorta. In that instance, however, the shunt was somewhat more complex in that it delivered blood from the ascending aorta into both the innominate artery and the distal aorta.

Cooley and DeBakey[50] reported a successful resection of a traumatic aneurysm of the distal aortic arch in a 31-year-old man, which had recurred five months following partial tangential aneurysmectomy. This was 1 of 7 cases in which these authors have resected aneurysms of the distal arch and descending thoracic aorta, with replacement by homologous graft. In these cases, and in 5 patients in whom coarctations of the thoracic aorta were similarly resected and grafted, they have been able to cross-clamp the aorta distal to the left common carotid artery, without the aid of shunt, with a mortality rate of 16.7 per cent. They advocate the use of moderate hypothermia, especially in poor risk patients, and attempt to avoid occlusion of the aorta for periods in excess of one hour.

Our patient, then, is the second reported case of aneurysm of the aortic arch due to closed trauma, associated with a fracture of a first rib,[26] and the third in which fracture of any rib is reported.[46] The 2 patients with fractured sterna,[41, 45] as well as that of Weisel[43] with fracture of the left clavicle, however, would seem to reflect similar etiological factors. It is possible, of course, that in other reported cases rib fracture was overlooked, or not mentioned, though actually present.

From the few available reports of surgeons who have had the opportunity to treat such lesions, it appears obvious that the aneurysm, if saccular in type,

should, if possible, be resected tangentially and the resulting defect repaired with preservation of aortic continuity during the procedure. Fusiform aneurysms, or those involving one half or more of the aorta's circumferences, should ideally be resected and replaced by homologous, or other, graft material, with or without the employment of a shunt, depending upon the condition of the patient, characteristics and location of the aneurysm, and individual experience of the surgeon. In instances wherein suitable graft material is not available, and the aneurysm does not lend itself to tangential resection, wrapping with reactive polyethylene, as described here, would seem to be a safe procedure, offering considerable benefit to the patient. No case of rupture following such a procedure has been reported to our knowledge. In case of progression in size of the aneurysm, or should symptoms warrant, a more extensive attack may be considered at a later date.

SUMMARY AND CONCLUSIONS

The records of all patients admitted to a large Veterans Administration Hospital with the diagnosis of fractured ribs were reviewed. Seventeen patients, 10 per cent, had fracture of a first rib. With the exception of 1 patient, all of these were produced by closed chest trauma, in most instances by sudden deceleration in an automobile accident in which the chest sharply struck the steering wheel.

Complications occurring in the latter series included two grave lesions involving structures within the mediastinum, one an esophageal diverticulum with tracheoesophageal fistula, diagnosed six months after injury, the other a fusiform aneurysm of the aortic arch, diagnosed more than two years after injury. The former lesion was treated by division and repair, the latter by wrapping with reactive polyethylene, both with good postoperative result.

Other complications in cases of first rib fracture included injury to brachial plexus and stellate ganglion, and an unusual obstruction of both subclavian veins from the pressure of excessive callus about healing bilateral fractures. Remaining complications in this group, and all of those in the series of fracture of ribs other than the first (except one instance of brachial plexus injury in a patient with fractures of second rib and clavicle), were the common sequelae of pleural puncture by the rib fragments.

The world literature pertinent to first rib fracture, traumatic tracheoesophageal fistula, and traumatic aneurysm of the thoracic aorta, has been reviewed.

On the basis of this survey, the following conclusions seem to be in order:

1. Trauma, sufficient to produce fracture of a first rib by indirect force, is capable of effecting injury to mediastinal soft parts.

2. Lesions of lesser magnitude than complete disruption of tracheobronchial tree or great vessel may be considerably delayed in development or in producing diagnostic symptoms or signs.

3. In dealing with closed thoracic injuries, especially those produced by high speed automotive accidents, one is obligated to search carefully for evidence of first rib fracture, which may be easily overlooked before callus formation begins.

4. Patients suffering such fractures, without early manifestations of mediastinal lesion, must be thoroughly examined at frequent intervals; for at least two years following injury. Each examination should include an x-ray of the chest.

5. Widening of the superior mediastinal shadow in the vicinity of the aortic arch following chest injury should be considered a sign of possible incomplete rupture of the aorta, or other great vessel, from which aneurysm may develop.

ADDENDUM

Since submission of the manuscript, an additional pertinent case has been treated at the Hospital of The University of Mississippi. This case will be reported in detail elsewhere,* but may be briefly described here.

The patient (B. W.), an 18-year-old Negro girl, was transferred from another hospital on Oct. 12, 1955, four weeks following an automobile accident. On admission she was found to have fractures of *both first ribs*, left clavicle, right radius, and right femur. The left lung was completely atelectatic. Bronchoscopy revealed complete occlusion of the left main-stem bronchus, 3 cm. beyond the carina. The patient had no respiratory distress and was afebrile. A diagnosis of complete severance of the left bronchus was made. Operation was deferred because of associated orthopedic conditions.

Left thoracotomy was performed on Dec. 7, 1955. The bronchus was found to be completely divided, and the ends separated. The bronchus was reanastomosed and the lung re-expanded. Two weeks after surgery, the left lung was well expanded and there was a minimum of pleuritic reaction.

Patient H. F. M. (No. 16, Table I) was seen on Mar. 22, 1956, fourteen months after the aortic aneurysm was wrapped with reactive polyethylene. Chest x-ray on that date revealed no change in the aortic shadow compared with films taken six months and eleven months previously. He has remained asymptomatic and able to work.

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COMPARATIVE STUDY OF POSTRESECTION MORBIDITY IN CASES WITH AND WITHOUT PRERESECTION THORACOPLASTY

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EXCISIONAL surgery in the treatment of pulmonary tuberculosis has led to gratifying results.[1-7] However, the method of obliteration of the pleural space following resection is still controversial. Various ways of coping with the situation, such as temporary phrenic paralysis, pneumoperitoneum, postresection thoracoplasty, concomitant thoracoplasty, extrapleural plombage, extrapleural pneumothorax, extraperiosteal plombage, pleurotent, etc., indicate the lack of uniformity in dealing with this problem. There are also some of the opinion that there is no need for any space-reducing procedure following resection unless a definite pleural complication, in the form of a persistent bronchopleural fistula and empyema, is present.[8] The controversy still exists today and each thoracic surgeon employs his own preferred method in handling the situation.

The idea of a space-reducing, preresection thoracoplasty has some appeal. This paper is a report of a comparative study of the postoperative morbidity in 135 consecutive pulmonary resections performed at the Battey State Hospital from August, 1950, to August, 1953. Resections performed because of thoracoplasty failure, pneumonectomies, and lower lobectomies have been excluded. Seventy patients who had not had preresection thoracoplasty and 65 who had resections performed after a thoracoplasty, some three weeks before the resection, were studied.

The type of preresection thoracoplasty done in this series consists of the subperiosteal resection of the second and third ribs, posteriorly, from the level of the transverse process to, anteriorly, within the mid-clavicular line, or anterior axillary line, depending upon the anticipated amount of space reduction necessary following the contemplated surgery. The undersurface of the first rib has also been stripped of the periosteum.

The complications studied in the postoperative period and used for comparison between the two groups are as follows: (a) difficulty in expectoration in the first forty-eight hours, necessitating repeated tracheal aspiration and/or bronchoscopic aspirations, (b) evidence of a small leak from the raw surface, as manifested clinically by delayed re-expansion of the remaining lung tissue as shown by x-ray, blood-tinged sputum, and the necessity for prolonged underwater deflation, (c) poor re-expansion of the lung, necessitating thoracentesis or the reinsertion of an intrapleural catheter, (d) definite bronchopleural fistula

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requiring further thoracoplasty for space obliteration, and (e) a definite purulent empyema necessitating drainage when thoracoplasty failed to correct the causative bronchopleural fistula.

Table I specifies the distribution of cases in regard to the extent of resection and shows a more or less comparable proportion in the two groups.

TABLE I. EXTENT OF RESECTION

	WITH PRERESECTION THORACOPLASTY	WITHOUT PRERESECTION THORACOPLASTY
Lobectomies	23	32
Segmental cases	42	38
Total number of cases	65	70

From Table II it seems that patients who have preresection thoracoplasty have a lower incidence of complication than those without. This will be more evident when the rate is divided among various types of complications (one case may have more than one complication). Table II also shows that the main difference in incidence of complication is in the patients in whom lobectomy was performed. This will be elaborated in Table III.

TABLE II. COMPLICATIONS

	WITH PRERESECTION THORACOPLASTY	WITHOUT PRERESECTION THORACOPLASTY
Lobectomies	8	22
Segmental cases	10	8
Total number of cases	18	30

TABLE III. INCIDENCE OF VARIOUS TYPES OF COMPLICATIONS WITH RESPECT TO EXTENT OF RESECTION

	WITH PRERESECTION THORACOPLASTY			WITHOUT PRERESECTION THORACOPLASTY		
	SEGMENTAL	LOBAR	TOTAL	SEGMENTAL	LOBAR	TOTAL
a. Difficulty in expectoration	8	7	15	2	6	8
b. Evidence of prolonged leak	2	3	5	4	16	20
c. Poor re-expansion of lung	3	2	5	5	14	19
d. Bronchopleural fistula	2	1	3	0	5	5
e. Empyema	0	1	1	0	1	1

After studying Table III, the following points are made evident: (1) There was a higher percentage of patients who had difficulty in expectoration in the group that had preresection thoracoplasty. (2) The major causes of postoperative morbidity, as evidenced by prolonged leak of air and poor re-expansion of the lung necessitating only minor corrective procedure, is about 1 to 4 in favor of those with preresection thoracoplasty. (3) Cases with previously performed space-reducing thoracoplasty are less likely to result in bronchopleural fistula. (4) The incidence of residual empyema, resulting from bronchopleural fistula, not amenable to postresection thoracoplasty, is about equal in those with and without preresection thoracoplasty. This seems to indicate that the collapse obtained is not as satisfactory in patients who have had a preresection thoracoplasty as in the patients who have not and whose chest wall, lacking the removed

ribs, is more pliable. (5) Finally, it seems that the difference in the incidence of complication is most marked in cases where lobectomy was performed (20 against 5 and 19 against 5), in the "b" and "c" categories, respectively. This, we believe, indicates that the ease of obliteration of pleural space is more significant in reducing such complications than the presence of the so-called raw surfaces at the segmental plane, as in segmental resections.

DISCUSSION

It is at once apparent that a preresection thoracoplasty calls for an additional stage of operation and with it the inherent danger of anesthetic accident, cardiac arrest, prolonged hospitalization and expense, increased suffering, psychic trauma, transfusion reaction, etc. It might also be said that a thoracoplasty disturbs the ventilatory function on the side of the operation, if not also on the contralateral side, as well as diminishes the remaining respiratory function on the side on which the operation has been performed.[8-10] However, on the assumption that the diaphragm is responsible for 70 per cent of the function of one lung and the intercostal musculature for the remaining 30 per cent, it appears that the disturbance of a two-rib resection is not likely to be a great detriment to the respiratory function on that side. We feel that, although we have no objective findings as to the amount of reduction of the respiratory function on the side of the operation by the type of preresection thoracoplasty we do, it should not be any more deleterious than allowing the diaphragm to overelevate, thus attenuating its function, and overdistending the rest of the lung, as happens in cases where no preresection thoracoplasty is done. This is especially believed to occur, should any pleural complications arise, as there is a greater likelihood of delayed obliteration of the pleural space in the latter group.

In cases where a postresection thoracoplasty is indicated, the disadvantage of additional operation and chest-wall deformity in the group with preresection thoracoplasty therefore does not exist. Even in cases which do not require postresection thoracoplasty, we believe, from the experiences presented in this paper, that the undesirable feature of an additional operation is, in most cases, balanced by the advantages in the postresection period. We also feel that this operation, in poor and questionable risk cases, provides an acute test as to the ability of the patient to undergo chest surgery.

A point worthy of mention is the "reversibility" of such preresection thoracoplasty. It has been found that one is able to convert the relaxing and space-reducing type of thoracoplasty into a definitive Alexander type in the second stage, if, for various reasons, a resection is found to be contraindicated, during or after the preresection thoracoplasty. This revision and second-stage thoracoplasty, consisting of removal of the first rib and the transverse processes of the second and third thoracic vertebrae and the removal of additional ribs and processes as indicated, is found to be well tolerated, with no dangerous amount of paradoxical motion of the decostalized chest wall.

As to the one-stage combined thoracoplasty and resection which was propounded by Iverson,[11] Samson,[12] and Conklin,[13] there seems to be unanimous agreement that it is desirable in selected cases only. It is also the consensus that, in spite of the various advantages of this one-stage procedure, the post-

operative morbidity is definitely increased. Stead,[14] in his excellent articles, has conclusive evidence to that effect. Its usefulness, therefore, is limited. Björk[15] favors a combination of pulmonary resection and his osteoplastic thoracoplasty, which is said to obviate the dreaded paradoxical motion of the decostalized chest wall. We have had no experience with that particular technique.

Last, but not of least significance, we feel that the preresection thoracoplasty affords the diseased area of the lung an opportunity to undergo a period of "selective collapse," a desirable condition which most of the phthisiologists in the days of artificial pneumothorax strove to obtain. This period of time between the preresection thoracoplasty and actual resection also allows adjustment of aerodynamics of the remaining and comparatively healthy lung. We believe such features should render the resection a safer procedure.

CONCLUSION

From the study of two more or less comparable groups of patients who have had pulmonary resection for tuberculosis, those with and those without preresection thoracoplasty, the data tend to show that the postoperative morbidity is four times less in patients who have had a preresection relaxing operation. The various merits and disadvantages of this procedure are discussed. We believe that, in selected cases, when a resection of lobar extent and a space-reducing problem are anticipated, a relaxing thoracoplasty done prior to pulmonary resection is of considerable value in reducing the postoperative morbidity.

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GIANT AIR CYST(S) AS A SEQUELA OF PULMONARY TUBERCULOSIS

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OUR attention has been directed recently to a series of patients, in this 1,800 bed hospital for pulmonary tuberculosis, who have in common a giant air-containing cystic space in the lung. These patients all had diagnoses of pulmonary tuberculosis and had been under treatment for different lengths of time. The air cysts in the lung fields found on x-ray could all be traced from areas of tuberculous infiltration in the series of films taken over the period of time while the patient was in the hospital. They represented the end result of continuous resolution and regression of the tuberculous process. They met all the criteria, roentgenologically, to be diagnosed as giant bulla of the lung, or pneumatocele. Resections were performed on all these patients and the specimens were examined pathologically. To our added amazement, no histopathologic evidence of tuberculosis could be found in the sections. Therefore, it seems that, were it not for the fact that these cases represent the sequelae of treated pulmonary tuberculosis, one would have no way of differentiating these cases from those of pneumatocele of other etiology. We believe that it might be worth while to present our experience and findings in these cases.

CASE REPORTS

CASE 1.—L. S. F. (B.S.H.), an 18-year-old Negro girl, was admitted to this institution on Nov. 24, 1952, with a diagnosis of pulmonary tuberculosis, far advanced. In addition, tuberculous complications of lymphadenitis, adenitis, and bronchitis were present. X-ray at the time of admission showed extensive involvement of the left lung, with almost total destruction, together with scattered disease in the right lung field (Fig. 1). On admission the patient was placed on streptomycin and para-aminosalicylic acid, which she received for approximately one year. In October, 1953, the patient was started on isoniazid and para-aminosalicylic acid, which she received up until the time of surgery. The sputum converted in October, 1953, and has remained negative since that time. The patient did remarkably well on the medical regime. The lesion in the right lung resolved nicely, but the patient progressed to the formation of giant bullas and emphysema in the left lung. A bronchogram made in the preoperative period showed damage to the entire left bronchial tree. In view of the destroyed lung, with large pneumatoceles present (Fig. 2) the patient was accepted for surgical therapy. On Feb. 10, 1955, a left pneumonectomy and concomitant thoracoplasty were done. The postoperative course was entirely uneventful and the patient was transferred back to the Medical Service in good condition, with no symptoms, sputum negative, and no respiratory embarrassment. The pathologic examination of the resected material showed complete destruction of the left lung, with giant, openly drained, air-containing spaces present in the resected lung. Direct smears and cultures of all upper lobe bronchi and corresponding parenchymatous lesions were negative for acid-fast bacilli. The patient is now (Oct. 1, 1955) being prepared for discharge.

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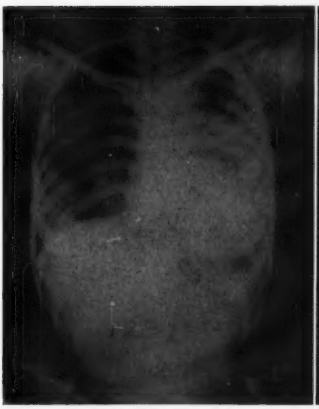

Fig. 1.

Fig. 2.

CASE 2.—C. J. (B.S.H.), a 23-year-old Negro man, was admitted March 26, 1951, with a diagnosis of pulmonary tuberculosis, far advanced. On admission the patient was started on pneumoperitoneum, which was maintained up until the time of surgery. Streptomycin and para-aminosalicylic acid were given for a total of eleven months after admission and then isoniazid and para-aminosalicylic acid were instituted in March, 1952. In addition to this, streptomycin was again instituted in July, 1952. The sputum converted in March, 1952, and remained negative until the time of surgery. At the time of admission, roentgenographically, the patient showed an essentially clear right lung, with exudative involvement throughout the left lung (Fig. 3). Under treatment, the lesions in the left

Fig. 3.

Fig. 4.

lung underwent considerable resolution, leaving behind numerous thin-walled, cystic lesions throughout practically the entire left lung (Fig. 4). A bronchogram made in October, 1952, showed extensive bronchiectasis of the left upper lobe, as well as the left lower lobe. In view of the extensive destruction, the patient was seen in surgical consultation and accepted for excisional surgery. On Jan. 15, 1954, a preresection thoracoplasty was done, with the removal of the second and third ribs and lysis of the first rib. On Feb. 3, 1954, the patient had a left upper lobectomy and removal of the superior segment of the left

lower lobe. The decision to save the basal segments of the lower lobe was made at the time of surgery, when it was felt they were essentially free of palpable disease and would represent a significant amount of functioning lung. The postoperative course, however, was marred by persistent localized pneumothorax at the apex of the pleural cavity and on Feb. 24, 1954, a postresection tailoring thoracoplasty was done, with complete obliteration of the residual air space. The postoperative course, henceforth, was entirely uneventful. The pathologic examination of the resected specimen showed a large, empty, upper lobe pneumatocele and saccular bronchiectasis, most marked in the lingula bronchus. All cultures of resected material were negative for acid-fast bacilli. The patient, being asymptomatic, was discharged Aug. 18, 1954, with a negative sputum. He was to continue drug therapy at home and was on a limited exercise status.

Fig. 5.

Fig. 6.

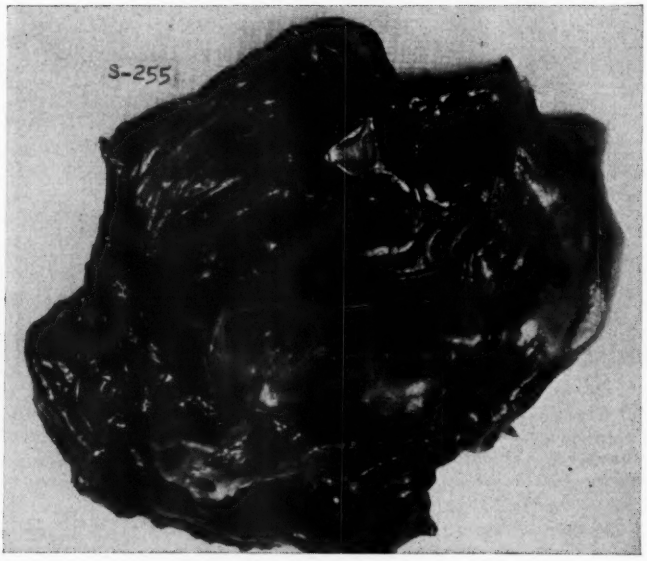

Fig. 7.

CASE 3.—A. A. (B.S.H.), a 28-year-old Negro woman, was admitted Feb. 9, 1953, with a diagnosis of pulmonary tuberculosis, far advanced; sputum positive. On admission the patient was given streptomycin, isoniazid, and para-aminosalicylic acid for forty weeks and then started with isoniazid and para-aminosalicylic acid which she received up until the time of surgery. The last positive sputum was a culture in March, 1953. Since that time the sputum has remained negative. Roentgenographically, at the time of admission, the patient showed extensive pneumonic and cavitary involvement of the right upper lung, with scattered disease in the lower portion of the right lung, as well as mid-lung field spread with cavitation of the left lung (Fig. 5). The disease responded very nicely to the drug therapy, with complete resolution of the disease in the left mid-lung field. The right lung underwent a considerable amount of resolution, but with the development of a giant air-containing cyst in the upper right lung field (Fig. 6). In view of this finding, the patient was accepted for excisional surgery. On Nov. 4, 1954, a right upper lobectomy was done. At the time of surgery, the giant air-containing cyst was seen to occupy the entire right upper lobe, with the right middle and right lower lobes presenting a satisfactory appearance. The postoperative course was essentially smooth. The pathology of the resected material revealed one large air-containing, cystlike structure, with moderate bronchiectasis and some atelectasis (Fig. 7). Cultures of the resected material failed to show a growth for acid-fast bacilli. The patient was discharged home. The sputum remains negative by smear and culture.

CASE 4.—M. R. (B.S.H.), a 22-year-old Negro woman, was readmitted to this institution on Dec. 8, 1952, with far-advanced pulmonary tuberculosis, bilateral (Fig. 8). The previous admission had been in December, 1949, and during that time she was hospitalized approximately twenty-eight months, received pneumoperitoneum and a short course of streptomycin and para-aminosalicylic acid. The sputum was positive at the time of discharge. On the present admission the sputum was positive on direct smear. In the last admission the patient was treated with streptomycin, isoniazid, and para-aminosalicylic acid. She received approxi-

Fig. 8.

Fig. 9.

mately twelve months of this therapy and in January, 1954, she was started on isoniazid and para-aminosalicylic acid, which she received up until the time of surgery. The sputum converted in December, 1952, and has remained negative since that time. The patient responded quite well to the medical regimen, the disease in the right lung undergoing considerable resolu-

tion and contraction and assuming a stabilized appearance. On the left side the disease progressed to destruction, with multiple giant cystic areas (Fig. 9). In view of the giant air-containing cysts remaining in the left lung, the patient was accepted for surgical therapy. On June 10, 1954, a left pneumonectomy with concomitant thoracoplasty was done. The postoperative course was quite smooth, with no evidence of respiratory embarrassment in the postoperative period. The patient was discharged April 29, 1955, with two-hour exercise and was entirely asymptomatic. The sputum remained negative.

CASE 5.—B. B. J. (B.S.H.), a 17-year-old white girl, was admitted April 8, 1953, with a diagnosis of pulmonary tuberculosis, far advanced; sputum positive. Since admission the patient has received streptomycin and para-aminosalicylic acid, as well as isoniazid for approximately one year. The sputum converted in April, 1953, and remained negative up to the time of surgery. Roentgenographically, at the time of admission, she showed an essentially clear left lung. The right lung was occupied by exudative pneumonic involvement of the entire lung (Fig. 10). The disease responded nicely to drug therapy, with resolution of the exudative components. She was left with a residual, however, of numerous air-containing cystlike structures and the general appearance of the left lung was that of a completely destroyed left lung (Fig. 11). A bronchogram made May 5, 1954, showed total destruction of the left lung. In view of the destroyed lung, with bronchiectasis, the patient was accepted for surgical

Fig. 10.

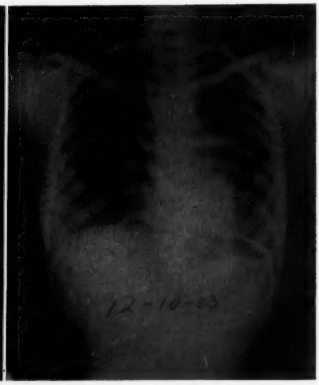

Fig. 11.

excision. On Aug. 11, 1954, the patient had a left pneumonectomy and a concomitant thoracoplasty. The postoperative course was entirely uneventful. Pathologic examination of the resected left lung showed a large-grained upper lobe cyst with tubular and saccular bronchiectasis. There were also small cavities in the posterobasal segments of the left lower lobe. Smears of the resected material were positive. However, cultures of this material were all negative. This patient is continuing to do quite well. She has been discharged to her home with sputum negative on smear and culture and is entirely asymptomatic with no respiratory embarrassment.

CASE 6.—D. M. (B.S.H.), a 26-year-old Negro man, was admitted to this hospital April 12, 1954, with a diagnosis of pulmonary tuberculosis, far advanced, and tuberculous complication of right pleuritis. On admission the sputum was positive on direct smear. The chest x-ray on admission revealed, on the right side, a huge cavity in the upper half and soft, scattered shadows of infiltration throughout the remaining portion of the right lung and the whole of the left lung (Fig. 12). Soon after admission the patient was given drug therapy, which consisted of streptomycin and para-aminosalicylic acid, with amazing clinical improvement. The sputum converted to negative two months after admission and

has remained negative. One year after admission, roentgenograms showed a destroyed upper lobe on the right side, which was replaced by a giant pneumatocele, occupying almost two-thirds of the right pleural space (Fig. 13). A bronchogram revealed the middle and lower lobes to be compressed toward the base of the pleural cavity and the superior division of the lower lobe on the right side to be bronchiectatic. On May 24, 1955, a right upper lobectomy and resection of the superior segment of the lower lobe were done, and a small wedge from the basilar division of the right lower lobe was removed, along with a tailoring thoracoplasty. The postoperative course was essentially benign, except for the necessity of frequent tracheal aspirations, as the patient was not able to expectorate secretions effectively. As of Sept. 1, 1955, this patient has been doing very well. He is now three and one-half months postoperative and, by x-ray, the remaining lung has completely re-expanded. The sputum remains negative. The resected specimen revealed one

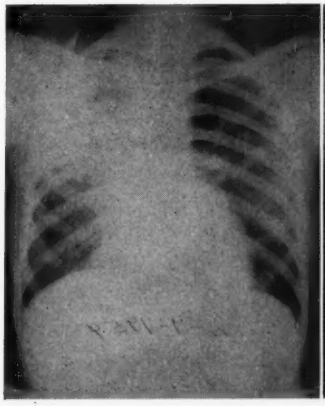

Fig. 12.

Fig. 13.

large "healed" cavity of the right upper lobe and several "healed" cavities of the superior division of the right lower lobe, with one active focus of residual fibrocaseous tuberculous disease and one minute focus of residual tuberculous endobronchitis of the superior division. Direct smears and cultures of the resected specimens were negative for acid-fast bacilli.

COMMENT

The subject of etiology and classification of various types of air spaces in the lung has long been well discussed and the medical literature already shows an overabundance of such articles. It is not the purpose of this paper to confound this crowded matter of discussion further. Since 1952, Cooke and Blades[1] have greatly clarified many aspects of this disease entity. It is now agreed that such an acquired form of air cysts of the lung develops as a result of the contraction of the surrounding tissue and the breakdown of the interalveolar septa and the coalescence and distention of the bulla. This mode of formation seems to be quite applicable to the air cysts in this particular series. This paper is an attempt to call attention to the fact that such pathology of the lung does occur as a sequela of "healed" cases of pulmonary tuberculosis.

From summaries of the 6 cases presented, it is to be noted that no histopathologic evidence of tuberculosis could be recognized in the excised specimens. Since 3 of the 6 patients had pneumonectomies, this lack of any residual tuberculosis deserves special consideration. Although it is understood that the modern antituberculosis measures and drugs can and do resolve a tuberculosis process in the lung, the completeness of the resolution is perhaps not quite appreciated. We are quite aware of the fact, however, that this is the exception rather than the rule.

Numerous cases which have not been included in this series, and which present more or less similar x-rays, are found after resection to be residual tuberculous cavity with active granulation tissue. They are not included in this series as their appearance does not exactly resemble that of the average giant cyst or cystic disease of the lung. Nevertheless, they are all thin-walled areas of increased radiotranslucency with no peripheral infiltration. As yet, we have not been able to discern any roentgenologic points of differentiation between the two groups.

Another point of interest lies in the question of desirability, if not of necessity, of antituberculosis drug therapy in these patients in the postoperative period, particularly in those patients who have had pneumonectomies and who show no evidence of tuberculosis in the entire lung. The question of necessary hospitalization also deserves to be seriously considered. Believing that tuberculosis is a systemic disease, it is our practice to treat such patients as any other tuberculosis patient who has had a resection. We do not believe, however, that this question is settled.

Our comment would not be complete if the question of the existence of "healed" tuberculous cavity is not brought out. The finding of a giant air cyst connecting directly to a lobar bronchus at the site of a previous cavity cannot be disregarded. Is it not possible that the contraction of surrounding tissue and distention of the original tuberculous cavity, which has been "sterilized" and "endothelized" by the antituberculosis drug, could happen hand in hand with the formation of some of these air cysts of the lung in a previously tuberculous patient?

SUMMARY

Six cases of giant air cysts of the lung in patients with previously proved pulmonary tuberculosis have been presented. The question of the pathogenesis of such lesions in which microscopic study shows no histopathologic evidence of tuberculosis has been raised.

REFERENCE

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LEFT CERVICAL, RIGHT THORACIC APPROACH FOR RESECTING CARCINOMA OF THE UPPER ESOPHAGUS

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NUMEROUS methods have been devised for resecting the upper third of the esophagus since this was first successfully performed by Garlock in 1937. The various modifications have been efforts to obtain either better exposure to facilitate the resection of the cancer-bearing esophagus, or to effect a reconstruction of the continuity of the food-bearing tube. Among the latter have been the utilization of intra-abdominal organs (stomach, jejunum, colon) transposed to the thoracic region and anastomosed either high in the thorax or in the neck. Each of the described procedures has certain advantages and limitations. The utilization of a left cervical incision, which takes advantage of the normal deviation of the esophagus to the left side of the neck, combined with a right thoracic incision, which avoids the difficulties inherent in dissecting about the arch of the aorta, has afforded the ready resection of a large segment of the esophagus. The techniques of this approach and the method of reconstruction shall be described in detail.

The patient was a 57-year-old white woman who presented a history of dysphagia of seven months' duration. One year previously she had consulted a local medical doctor who diagnosed a gastric ulcer and treated her with diet. Seven months before, she had developed dysphagia which had been progressive. An esophagram revealed an extensive obstruction which extended from the level of the pharynx inferiorly for a distance of over 8 cm. There had been a loss of 20 pounds during the preceding year, erratic bouts of fever of unknown etiology, and repeated "sore throats."

The past history of this patient was significant in that she had had a carcinoma of the thyroid removed thirty-eight years previously and had been given large doses of x-ray postoperatively.

Physical examination was not remarkable, and the patient was found to be in a rather good state of nutrition despite dysphagia of almost a year's duration. The neck presented evidence of radiation fibrosis, the result of previous x-ray therapy. The remainder of the physical examination was negative.

Laboratory studies were normal. Blood count was within normal range: hemoglobin 84 per cent, red blood count 4.3 million per cubic millimeter, white blood count 6,300 per cubic millimeter. Tests of liver function revealed phosphorus 3.6 mg. per cent, alkaline phosphatase 3.1 S.J.R. units, bilirubin 0.4

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mg. per cent, cephalin flocculation 1+, thymol turbidity less than 5 units, total protein 6.5 Gm. per cent, albumin 3.2 Gm. per cent, globulin 3.1 Gm. per cent, choline esterase 0.55 units.

An esophagoscopy revealed almost complete esophageal obstruction and a biopsy was positive for papillary carcinoma. Accordingly, on June 11, 1954, the resection of the esophagus and repair of the ensuing defect was accomplished in the following manner.

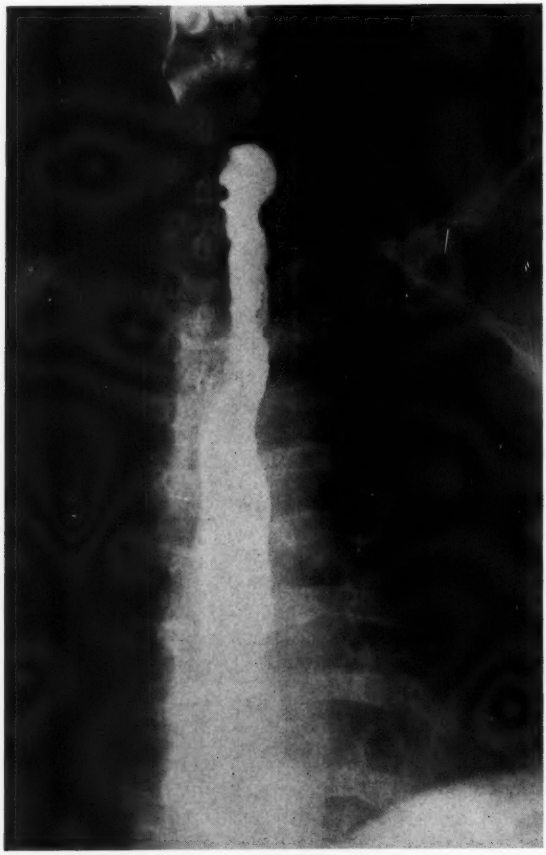

Fig. 1.—An esophagram which reveals a linear obstruction of the cervical and upper thoracic esophagus due to a carcinoma.

OPERATIVE TECHNIQUE*

A left cervical incision was made along the medial border of the left sternocleidomastoid muscle extending from the angle of the mandible to the sternal

*The operation was performed in conjunction with Dr. James Baldwin.

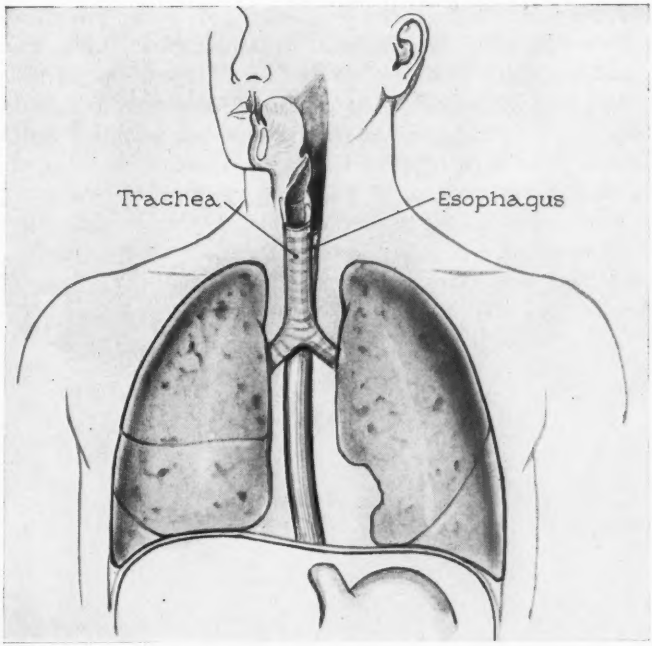

Fig. 2.—A diagrammatic anatomic drawing illustrating the left cervical deviation of the esophagus. A left cervical incision permits excellent exposure for operative manipulation of the esophagus.

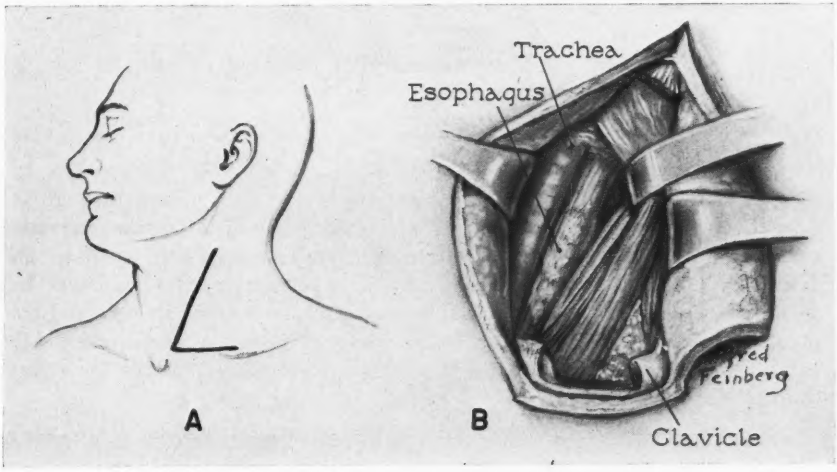

Fig. 3.—The cervical exposure of the esophagus. *A*, Illustrates the incision used. *B*, The esophagus is exposed. The sternomastoid muscle has been removed. The strap muscles are retracted. The medial half of the clavicle has been resected due to destruction from previous irradiation. (This step is not usually indicated.) The esophagus bearing the tumor is visualized.

notch, at which point a horizontal component of the incision was made extending laterally toward the left. The skin and subcutaneous tissue which was markedly atrophic and fibrotic, the result of previous irradiation, was retracted and the sternomastoid muscle resected. The clavicle, which was found to be softened and friable (the result of previous irradiation), was mobilized and the medial third resected. The sternohyoid and omohyoid muscles were then severed, and the remaining strap muscles of the neck retracted laterally. This gave excellent exposure of the entire cervical esophagus which was easily mobilized (Fig. 3). The tumor, which was in the lumen of the esophagus, could be felt infiltrating the musculature, but it was definitely limited to the esophagus and had not infiltrated the contiguous structures. The proximal portion of the esophagus at the level of the esophageal-pharyngeal junction was severed, a square of gutta percha was then tied about the distal stump of the

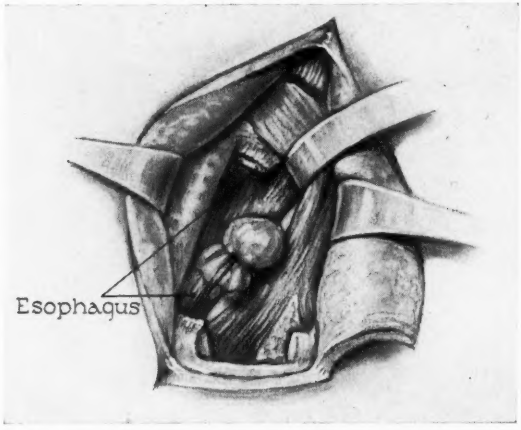

Fig. 4.—The esophagus has been transected at the pharyngo-esophageal junction. A square of gutta percha has been tied about the distal stump of the severed esophagus and the silk string delivered into the right chest.

esophagus by a long heavy silk thread which was then placed through the sternal region into the right intrathoracic cavity. The distal esophageal stump containing the gutta percha protective covering was then bent on itself and delivered into the mediastinum. The proximal pharyngeal stump was left open (Fig. 4). The wound was then packed with moist saline sponges and temporarily closed with Michel skin clips. It was covered with a moist towel and the patient was then turned to the left side and placed in a position for a right thoracotomy.

Thoracic Portion of the Resection.—An anterolateral incision was made in the right chest wall, in an inframammary position. The fifth rib was exposed and removed. This permitted exposure of the right chest cavity. There were a few adhesions of the lung to the surrounding chest cavity, which were freed. The azygos vein was divided, and the esophagus was readily mobilized (Fig. 5).

By gentle traction of the silk thread which had been delivered into the mediastinum during the cervical portion of this operation, the distal severed portion of the esophagus was delivered into the right thoracic cavity (Fig. 6). After the esophagus was completely mobilized, it was transected at a level about 10 cm. distal to the pharyngeal-esophageal junction.

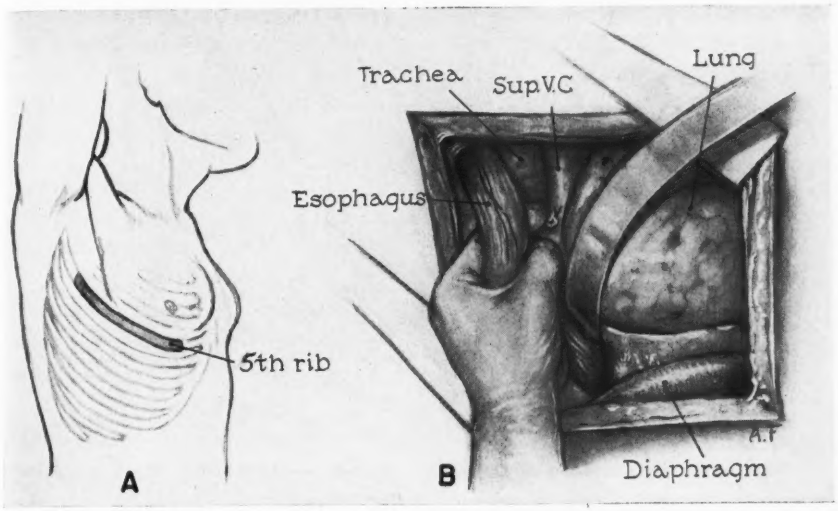

Fig. 5.—The thoracic phase of the esophagectomy. *A*, The anterolateral thoracic incision extending in the inframammary fold. The fifth rib was excised. *B*, The esophagus is mobilized and the string inserted from the cervical region is visualized.

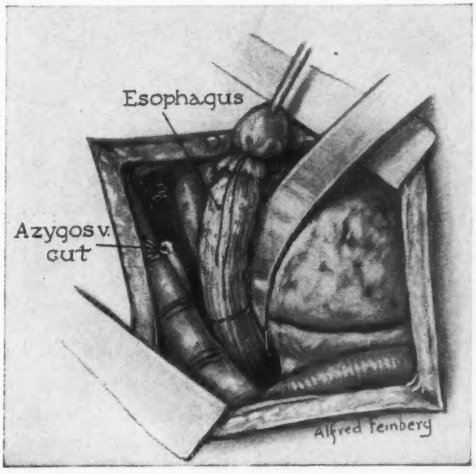

Fig. 6.—Traction on the silk suture delivered the transected esophagus into the chest cavity.

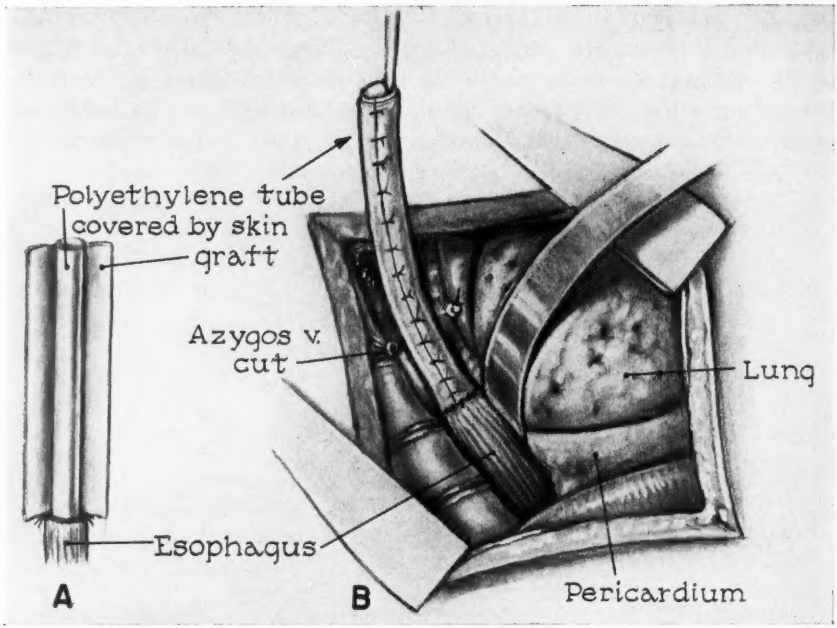

Fig. 7.—The reconstruction of the cervical thoracic esophagectomy. *A*, A split-thickness skin graft has been molded about a Berman-type polyethylene tube and the skin graft is being anastomosed to the distal esophagus. *B*, The thoracic anastomosis has been completed and the reconstructed esophagus is being delivered into the natural esophageal bed in the cervical region.

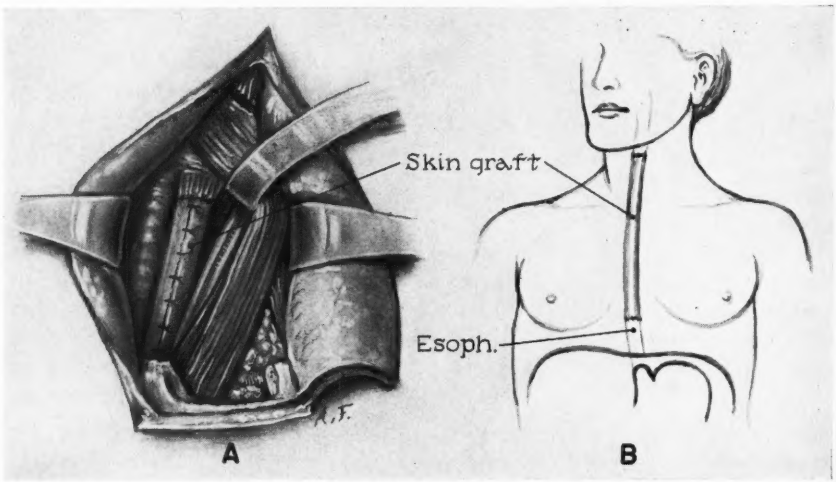

Fig. 8.—*A*, The cervical repair of the reconstructed esophagus. The skin graft has been sutured to the pharyngeal stump. *B*, A diagrammatic representation of a reconstructed esophagus.

Repair of the Ensuing Defect.—The resulting defect was closed by utilizing a Berman-type polyethylene tube, about which was placed a split-thickness skin graft taken from the patient's lower abdomen. A flat piece of skin was molded about the polyethylene tube, and the polyethylene tube was then inserted into the distal esophagus, but in no way anchored there. The split-thickness skin graft was sutured by interrupted silk sutures to the distal stump of the esophagus (Fig. 7, *A*). Following this anastomosis, the skin-covered polyethylene tube was placed into the natural bed of the esophagus and delivered into the cervical region (Fig. 7, *B*). The chest wound was then closed in the normal manner, the patient was placed in the supine position and the cervical wound was then reopened. The polyethylene tube was then anchored to the pharynx by two interrupted silk sutures, after which the pharyngeal skin graft anastomosis was made, again utilizing interrupted No. 4-0 silk sutures. The neck wound was closed. A drain was left in the neck wound, and under-water drainage was established for the right thoracic cavity (Fig. 8).

The patient tolerated the procedure well, there was a minimum of blood loss, and a 500 c.c. transfusion was given during this operation which lasted approximately two hours.

POSTOPERATIVE COURSE

Postoperatively there was evidence of leakage from both anastomotic sites. There developed a pharyngeal-cervical fistula with free drainage of mucus and, on efforts to swallow, fluids presented in the left neck region. In addition, there was copious drainage of serosanguineous material from the right chest. This persisted for approximately two weeks, during which time the patient was maintained exclusively on intravenous feedings. Electrolyte abnormalities developed and were corrected. A gastrostomy was performed three weeks postoperatively for feeding purposes, which functioned satisfactorily, and the patient was discharged from the hospital on July 18, 1954.

She then developed an empyema necessitatis due to drainage material which formed a pathway from the left cervical region, through the posterior mediastinum, and thence out through the right chest. The patient was readmitted to the hospital Aug. 5, 1954, and drainage was instituted which cured this complication. She then developed dysphagia and a dilatation of the cervical esophagus was performed on Dec. 21, 1954. She has remained free of evidence of cancer. She now suffers dysphagia on efforts to swallow solid food and a recent esophagoscopy has revealed some stenosis at the anastomotic level. The left vocal cord is paralyzed due to severance of the left recurrent laryngeal nerve.

The resected specimen consisted of a large, polypoid ulcerated tumor which measured over 5 cm. in its largest diameter and encircled approximately five-sixths of the wall of the esophagus. The tumor invaded submucosa and muscularis. Histologically, the tumor was an epidermoid carcinoma, deeply invading the muscularis.

The tissue removed from the posterior mediastinum was examined for presence of metastases from this carcinoma and, although over 15 lymph nodes were removed in this dissection, none was found to contain metastases.

DISCUSSION

This successful resection of a rather extensive cancer of the esophagus demonstrates the feasibility of taking advantage of the normal anatomy of the esophagus to obtain excellent exposure through a double incision. The one in the left cervical region takes advantage of the tendency of the normal

Fig. 9.—The patient one year after operation showing good nutritional status. The scar in the clavicular, upper mediastinal region is the site of previous irradiation, the scar of the lower abdomen is the site where the skin was removed for reconstruction of the esophagus.

esophagus to swing toward the left in the neck and affords excellent exposure for mobilization and dissection of the esophagus in this region. The technique of tying gutta percha around the distal stump of the esophagus and inverting the esophagus into the right chest is similar to the procedure utilized in the abdominoperineal resection of rectal cancer, where the abdominal phase of the operation is concluded by turning the resected bowel on itself and delivering it into the pelvis for removal by means of the perineal approach. The technique has been found to be simple, and in the case herein reported the

A.

B.

Fig. 10.—*A*, The left clavical scar one year after operation. *B*, The right thoracic incision one year after operation.

esophagus was delivered into the chest and mobilized with great ease. The utilization of the right chest offers the usual freedom for manipulation of the esophagus without interference from the arch of the aorta. It was found most satisfactory in the case herein reported, and the esophagus was mobilized and resected with ease.

The reconstruction of the esophageal defect always poses a problem, and the technique just described was chosen because of fear of bringing intra-

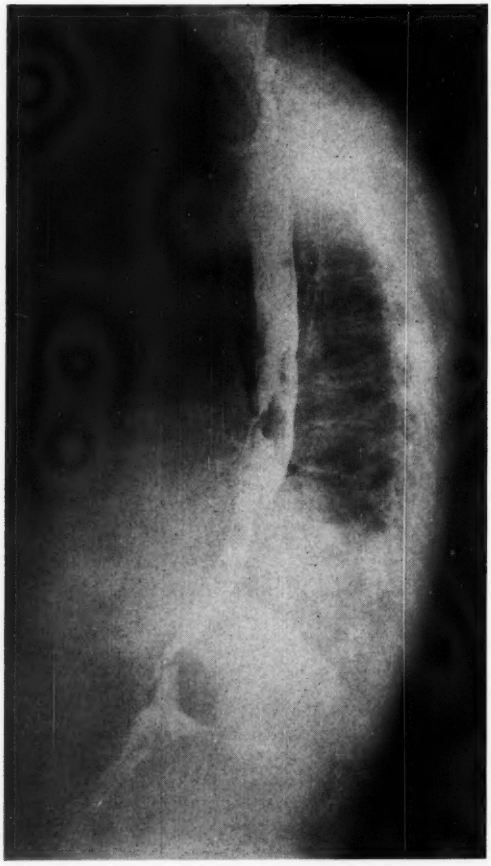

Fig. 11.—A lateral esophagram illustrating the reconstructed cervical, upper thoracic esophagus, taken one year after the operation.

abdominal organs into the heavily irradiated cervical and upper thoracic regions. The tissue of the neck was atrophic and fibrotic and it was felt that possibly a better anastomosis could be obtained by utilizing a split-thickness skin graft to effect the reconstruction. The polyethylene tube was used as a stent to prevent contracture of the anastomosis. The polyethylene tube has

remained in place and recent roentgenograms have revealed that swallowed food goes both through the polyethylene tube and around it. Attempts to remove the polyethylene tube through the oral approach have been unsuccessful because of failure of visualization. The polyethylene tube has not been successful in preventing contracture of the cervical anastomosis.

The medial portion of the left clavicle was removed in this instance because it was so badly damaged by previous x-ray therapy. It is not recommended that it be removed routinely because the operation can be performed without any intervention into the clavicle. The postoperative leakage at the anastomotic sites was possibly the result of the irradiation atrophy in the neck, but the case does demonstrate the well-known fact that healing will eventually occur if conservative measures are utilized.

The patient has remained well and apparently free of disease for almost two years after the initial resection. Because of a stricture at the sight of the superior anastomosis, an exploration of the pharynx and the fabricated esophagus was performed on May 1, 1956. No evidence of recurrent neoplasia was encountered. The new esophagus, made of a split-thickness skin flap, appeared healthy, moist and, except for a stricture at the site of the anastomosis, was patent throughout. The plastic tube was inferior to the clavicle and could not be removed by the cervical approach. A plastic repair of the stricture was effected.

SUMMARY

1. A case is reported of a carcinoma which involved a major segment of the esophagus. The possibility exists that this carcinoma could be the result of x-ray therapy which the patient received thirty-eight years ago.

2. The utilization of a left cervical approach and a right thoracic approach permitted resection of the major portion of the esophagus with relative ease.

3. The reconstruction of the defect by utilizing a split-thickness skin graft, supported by a polyethylene tube, and placed into the normal esophageal bed, was successful. The skin graft has apparently taken in its entirety.

4. The patient had leakage from both proximal and distal sites of anastomoses, which healed spontaneously. Drainage must be maintained for prolonged periods.

5. The patient, although apparently free of disease one year and nine months after resection, is suffering from contracture at the site of the cervical anastomosis which produces dysphagia. She is suffering from some dyspnea as a result of fibroses in the right chest, possibly secondary to the empyema necessitatis which developed subsequently to the first operation.

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RHABDOMYOSARCOMA OF THE ESOPHAGUS

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RHABDOMYOSARCOMA of the esophagus is an extremely rare tumor. A search of the available bibliographic data has revealed only four previously reported tumors of this type in this location. In 1950, Thorek and Neiman[5] reviewed the world literature and reported the first such tumor to be successfully resected surgically and the fourth to be recorded in the literature. Credit for previous reported cases was given to Wolfensberger,[6] Glinski,[2] and Dvorak[1] in that report. To the best of our knowledge, the present report is the second to record a successful esophageal resection for rhabdomyosarcoma.

CASE REPORT

J. R., a 54-year-old Negro man, was admitted to the hospital on June 22, 1955. He was known to have ingested considerable quantities of alcohol over many years. He had been hospitalized eight weeks previously and a diagnosis of pneumonitis had been made. Response to antibiotic treatment was prompt, and he was discharged free of complaints after two weeks of hospitalization. Approximately one week later he developed difficulty in swallowing solid foods. The dysphagia advanced rapidly, but he was always able to take liquids. In the ensuing five weeks he lost approximately 40 pounds. His appetite was good, but only occasionally was he able to swallow soft food.

Examination: The examination was unremarkable. His weight was 133 pounds. There was evidence of marked weight loss. The blood pressure was 128/70 Hg, pulse 80, and respirations 20 per minute. There were no teeth in the upper jaw and those in the lower jaw were very poor. No residual chest abnormalities were noted, no adenopathy was apparent, and the liver was not palpable.

Laboratory Data: Hemoglobin, 46 per cent; red blood count 2.6 million; white blood count, 8,700 with a normal differential. The serum protein was reported as 10 Gm. per cent, serum globulin 7.2 Gm., and albumin 2.8 Gm. per 100 c.c. of serum. The urine was reported negative for Bence-Jones protein. The blood urea nitrogen was 9 mg. per cent and the fasting blood sugar was 98 mg. per cent. The prothrombin time was normal.

An x-ray study of the esophagus revealed considerable esophageal dilatation above a markedly irregular constriction situated just above the level of the diaphragm (Fig. 1). Roentgenograms of the chest were negative. Esophagoscopy was done and an irregular lesion was found which bled easily and was visualized 35 cm. from the maxillary border. Biopsy was performed and, upon microscopic examination, the pathologist reported a rhabdomyosarcoma.

A plastic nasal-feeding tube was passed into the stomach with little difficulty and a milk-protein hydrolysate-vitamin formula fed via the tube. The daily caloric intake was 3,000 calories in approximately 3,000 c.c. of formula. Within twelve days he had gained 9 pounds and felt much more energetic.

Operation: On July 7, 1955, thoracotomy was performed through the bed of the resected left eighth rib. The lower esophagus was easily mobilized and found to contain

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a tumor just above the level of the diaphragm (Fig. 2). The enlargement appeared fusiform with a grossly intact musculature. Palpation revealed that a lesion lay within the lumen which slipped up and down about 1 inch and which had its attachment on the right anterolateral aspect of the esophagus. In the region of attachment, a thickening within the musculature of the esophagus was apparent on palpation. Because of the histologic appearance of the biopsy specimen taken previously, a resection was deemed advisable.

Fig. 1.—Roentgenogram of lateral view of chest showing defect in distal esophagus on barium-swallowing function.

Fig. 2.—Profile view of tumor in opened specimen.

The diaphragm was opened through the dome, and palpation of the contents of the peritoneal cavity was negative except for the presence of two small, firm, globular nodules in the superior aspect of the right lobe of the liver. Because of the approach, direct inspection of these lesions was not possible. Whether they represented metastatic lesions remains to be determined.

The stomach was mobilized superiorly by dividing gastrocolic omentum and left gastric artery on greater and lesser curvatures, respectively. The stomach was then divided to include the upper one fourth in the resected specimen, closed on the lesser curvature aspect, and anastomosed to the esophagus at a level about 4 cm. above the lesion. The diaphragm was repaired, and the chest was drained through a single tube placed posterolaterally. Water-seal drainage was applied. The chest was closed.

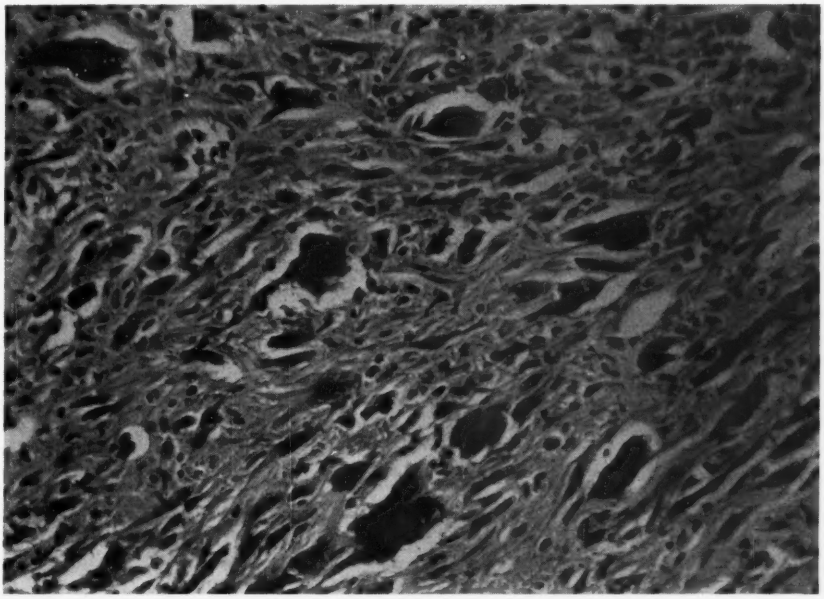

Fig. 3.—High-power photomicrograph of lesion (×290; reduced ¼).

The Levin tube which had been placed into the gastric remnant was inadvertently withdrawn when the endotracheal tube was removed. It was not replaced.

The patient was allowed fluids by mouth on the sixth postoperative day, and solid food was given on the ninth postoperative day. His convalescence was entirely uneventful, and he was discharged on July 26, 1955, the nineteenth postoperative day.

Pathology Report.—Gross specimen: The specimen consisted of the lower end of the esophagus and a small portion of the cardiac end of the stomach. Approximately 7 cm. of esophagus was included and the stomach measured 3 cm. along the lesser curvature. Attached to the portion of the esophagus and extending to within approximately 1.8 cm. of the upper margin there was a cylindrical mass measuring 10.4 cm. in length and 4.7 cm. in diameter. This was firm and fleshy. The surface was mottled red and purple. At one side there was an area of irregular fungating yellowish tissue which had extended through the capsule. Areas showed some infiltration into the wall of the esophagus as well as what appeared to be a few small satellite nodules. The mass was attached by a

broad pedicle measuring approximately 5.5 by 3.5 cm. It caused a bulge in the outer surface of the esophagus but grossly did not extend through. Cross sections through the mass revealed a firm, yellow tumor which retracted from the cut surface. The tumor was fleshy in consistency and had a typical fish-flesh appearance. On sections through the posterior surface, it was seen to extend through the wall of the esophagus and to be covered only by a thin membrane.

Microscopic: (Fig. 3.) Sections of the tumor mass showed the same bizarre appearance and the same grotesque histology as was seen in the biopsy. Many of the cells were elongated and straplike with a tendency to be arranged in parallel groups. However, this tendency was not marked. In addition, there were numerous grotesque tumor giant cells. These typically had extremely large and hyperchromatic nuclei which showed tremendous variation in size and shape. They were frequently lobulated. They showed coarse clumping of chromatin and tremendous karyosomes. Many of the bizarre cells showed the abundant cytoplasm to be divided into parallel, fine beaded fibrils. There was superficial ulceration of the tumor, and the tumor was seen to extend throughout the depth of the wall. The serosal covering mentioned previously was imperfect. In addition, a very tiny area of firmness that was found within the adjacent fat, was found to be a portion of the tumor. There was irregular invasion of adjacent fat. Phosphotungstic acid stains were prepared, but cross striations were not convincingly demonstrated.

Diagnosis: Rhabdomyosarcoma.

DISCUSSION

Explanation for the occurrence of a malignant striated muscle tumor in an area consisting of smooth muscle has been attempted by Thorek and Neiman.[5] The presence of an embryonic rest or metaplasia were possibilities advanced by these authors. Whether or not such an explanation need be advanced in their case is questionable. The lesion described by them occurred in the mid-esophagus where striated and smooth muscle cells are said to coexist.[3, 4] In the case herein reported, such an explanation seems reasonable.

SUMMARY

A case of rhabdomyosarcoma of the esophagus resected surgically with survival of the patient is reported. We believe it to be the fifth such tumor recorded in the medical literature and the second to be successfully resected.

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POSTEROANTERIOR CHEST ROENTGENOGRAM IN TWO TYPES OF ANOMALOUS PULMONARY VENOUS CONNECTION

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IT HAS been said that conventional roentgenology contributes only about 10 per cent toward the diagnosis of heart disease. No doubt, this figure is in many cases an overestimation. But, on the other hand, there are certain types of cardiovascular malformations in which routine methods of roentgenology can contribute about 100 per cent toward the anatomic diagnosis. Reference is specifically made, in this communication, to the two types of anomalous connection of the pulmonary veins that can be diagnosed from the routine posteroanterior chest roentgenogram. These two types are:

1. The type in which all of the blood of both lungs drains to the right superior vena cava by a partially persistent left superior vena cava or left vertical vein. This is the so-called figure-of-eight type or "cottage-loaf"[9] type of total anomalous pulmonary venous connection. About 30 cases of this condition have now been described in the literature,[4-10] the majority in the last three years.

2. The type in which part or all of the blood from the right lung drains into the inferior vena cava. Fewer cases of this type have been described,[1-3, 7] probably owing partly to the fact that the roentgenogram is not as spectacular as that of the figure-of-eight type, and the abnormality is more easily overlooked.

Several cases of each type are described in this communication, the main reasons being to add these cases to a not as yet overburdened literature, as well as to draw the attention of those not familiar with these lesions to a very fascinating group of cases. The value of the posteroanterior roentgenogram is stressed in the diagnosis of these conditions, and the spectacular use to which tomography can be put in demonstrating the right anomalous pulmonary veins is illustrated. No attempt is made to discuss the interesting catheterization data provided by these cases.

FIGURE-OF-EIGHT TYPE OF TOTAL ANOMALOUS PULMONARY VENOUS CONNECTION

The term "anomalous pulmonary venous *connection*" is used to differentiate the state of affairs when pulmonary veins are normally connected with

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the heart but *drain abnormally* (for example, preferential drainage of the right pulmonary veins to the right atrium through an atrial septal defect).

The two diagrams in Fig. 1 illustrate the general anatomy of the venous anomaly in this type of case.

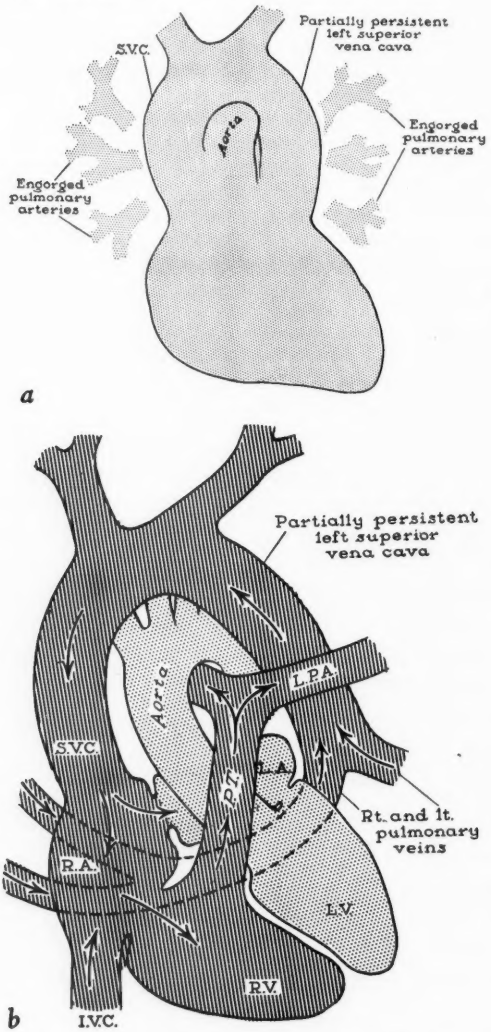

Fig. 1.—Diagrams explaining (*a*) the roentgenographic appearance, and (*b*) circulatory anatomy in the figure-of-eight type of total anomalous pulmonary venous connection.

It is obvious that if there is no atrial septal defect, the condition is incompatible with life for more than a short while. If an atrial septal defect is present but not of sufficient size, life is in danger owing to the large burden

on the right ventricle. In these cases the lung fields will probably show marked engorgement, since the systemic and most of the pulmonary venous blood will recirculate through the lungs. If the shunt from the right to the left atrium is large, there will be an equitable sharing of blood between the two ventricles. It is probable that this is the situation in those patients who have relatively little difficulty. Theoretically then, the less difficulty these patients have, the more normal should the peripheral pulmonary vascularity appear; while the more trouble they have, the more engorged will be the appearance of the lung fields.

The roentgenologic finding par excellence in these cases is the figure-of-eight configuration of the cardiac silhouette, as is explained in Fig. 1. Fluoroscopically, the upper part of this shadow, which is composed of the left and right superior venae cavae, will show a gentle pulsation, whereas the pulmonary trunk and its branches may show considerable exaggeration of pulsation as compared to normal.

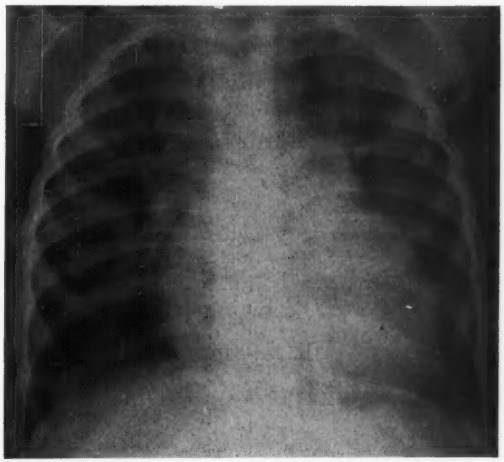

Fig. 2.—Case 1. Figure-of-eight type of total anomalous pulmonary venous connection in a boy, aged 3 years. Note the bilateral mediastinal widening.

CASE 1.—A boy, aged 3 years, had suffered from "heart trouble" since birth. The child was blue for the first few days, and after that the mother noted blueness of his hands and feet when she gave him a bath. In the newborn period, bilateral inguinal hernias developed, and a right herniorrhaphy was attempted at 4 months of age. The child was said to have "passed out" on the operating table. At this time a murmur was first noted. The child would fatigue easily and on some days was breathless all the time. He squatted frequently.

On examination there was slight cyanosis of the hands and feet, and the cardiologist reported a moderate systolic murmur, maximal in the midprecordial area, well heard toward the apex but not in the left subclavicular area.

A chest roentgenogram (Fig. 2) showed a rounded shadow projecting on each side of the superior mediastinum, the appearance being suggestive of the figure-of-eight sign. Fluoroscopically, pulsations of pulmonary vessels did not appear abnormal.

Cardiac catheterization was performed and confirmed the presence of the figure-of-eight type of total anomalous venous connection with an atrial septal defect; some of the findings suggested, in addition, a ventricular septal defect. Fairly marked pulmonary hypertension was found, but the pulmonary flow increased considerably when the child breathed 100 per cent oxygen.

Although the potential surgical correctability was recognized, it was decided to postpone such an attempt for some time, and it was suggested that the child be returned at a future date for further consideration.

CASE 2.—A boy, aged 4½ months, was brought to the Mayo Clinic for evaluation of congenital heart disease. The child's color was good at birth, but on the second day he was thought to have bronchopneumonia, and was hospitalized for eight days. Following dismissal from hospital, feeding difficulties were encountered, the child vomiting with each feeding. At about 3 months of age he gradually began to refuse feedings, and a cough developed. Oxygen was required on occasions during the following month. The

Fig. 3.—Case 2. Wide superior mediastinal shadow and pulmonary vascular engorgement due to total anomalous pulmonary venous connection in a boy, aged 4½ months.

child was admitted to the Clinic about this time in rather poor condition, and until the time of operation on May 26, 1955, he seemed to lose ground gradually. The chest roentgenogram (Fig. 3) revealed markedly engorged lung fields, and the presence of a rounded upper mediastinal shadow prompted the suggestion of total anomalous pulmonary venous connection with an inadequately large atrial septal defect. The electrocardiogram was reported to show evidence of right ventricular hypertrophy and right atrial enlargement. Cardiac catheterization was performed and dye-dilution curves were made. The findings were reported to be indicative of total anomalous pulmonary venous connection with an atrial septal defect and severe pulmonary hypertension.

Since the prognosis without treatment for this child was exceedingly poor, and because of encouraging work being done with the mechanical pump-oxygenator system, surgical correction of the defect was recommended to the parents, the risk of operation being emphasized.

A complete anatomic correction was therefore performed, and in the immediate postoperative period the child was in excellent condition. However, the arterial oxygen saturation gradually began to fail, and the child died in pulmonary edema about eight hours after operation.

CASE 3.—A housewife, aged 45 years, came to the Clinic for investigation of her heart. Although she had always considered herself to be in good health, she recalled that as a child she had been unable to keep up with her playmates because of dyspnea. Since the birth of her second child, eight years before, she had noted increasing exertional dyspnea on effort, as well as palpitation at rest. She had also noted some cyanosis, worse on exertion. She had had three miscarriages, then two uncomplicated births, twelve and eight years before. At no time had her physician noted anything concerning her heart.

Examination revealed slight cyanosis of the oral mucosa, fingers, and feet. There was no clubbing of the fingers. The electrocardiogram indicated right ventricular hypertrophy. A roentgenogram (Fig. 4) demonstrated the classic figure-of-eight configuration as seen in the type of total anomalous venous connection under discussion in this paper. The pulmonary vessels gave the impression of being markedly engorged.

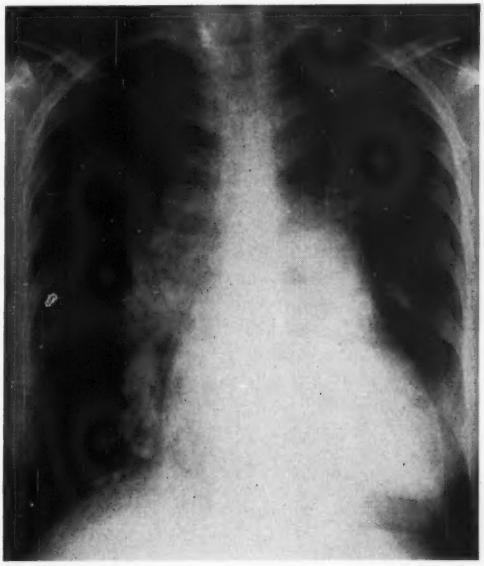

Fig. 4.—Case 3. Posteroanterior roentgenogram of a housewife, aged 45 years, demonstrating marked engorgement of the pulmonary vessels and the bilateral superior mediastinal widening as seen in the figure-of-eight type of total anomalous pulmonary venous connection.

Cardiac catheterization was performed, and the presence of total anomalous pulmonary venous connection with an atrial septal defect was confirmed. It was also discovered that the patient's condition was at this time complicated by severe pulmonary hypertension, the pressure in the right pulmonary artery being 119 mm. Hg systolic and 56 diastolic. The systemic oxygen saturation during the examination, as recorded by the earpiece, was 80 per cent.

An angiocardiogram was attempted but the patient was apparently sensitive to iodine, and the attempt was abandoned.

A surgical consultation was obtained, but, for the present, it was decided to postpone operation.

Comment.—It would seem reasonable to expect that, in a case of total anomalous pulmonary venous connection, if there were a large atrial septal defect, and if the blood that enters the right atrium divided optimally between

the right and the left atrium, the lung fields on the roentgenogram would appear normal, that is, the pulmonary vessels would not appear engorged. If, however, there is some reason, such as, for instance, an atrial septal defect that is too small, or some other factor that causes a larger amount of blood to pass through the right side of the heart than through the left side, then one would expect pulmonary vascular engorgement. It is probable that in all such cases the condition will proceed eventually to pulmonary hypertension and increasing cyanosis. Furthermore, the greater the obstruction to an initial right-to-left flow at the atrial level (small atrial septal defect or patent foramen ovale), the bigger the patient's problem becomes, as the right side of the heart becomes overloaded, the lungs tend to "drown," and the systemic circulation is deprived of blood; in the extreme case, in which no communication exists between the atrial chambers, life is of course impossible.

CASE 4.—In 1951, a woman, aged 52 years, came to the Clinic because of backache, abdominal discomfort, burning on urination, and some frequency. Most of these complaints dated since a hysterectomy in 1950. She stated during the examination that she had been a blue baby, and that she suffered from dyspnea on mild exertion. Her blood pressure was approximately 90 mm. Hg systolic and 60 diastolic, the heart rate was 68 beats per minute and the rhythm was regular. It was noted that there was a harsh systolic murmur over the precordium. There were slight clubbing of the fingers and toes and cyanotic mottling of the hands and feet. The blood count showed secondary polycythemia, which was considered to be due to a congenital heart condition. The electrocardiogram showed right axis deviation. A chest roentgenogram and fluoroscopy showed a bilateral upper mediastinal widening, and there was thought to be some increased prominence of the pulmonary vascular markings. Pulsations of the pulmonary vessels were not considered to be abnormal. The mediastinal shadow was noted to have a quiet expansile pulsation, and it was thought that the shadow might be that of a smoothly dilated aorta.

In reviewing a group of films recently, my colleagues and I came across the chest roentgenograms of this patient (Fig. 5), and the probability of total anomalous pulmonary venous connection was suspected. Inquiries were therefore made about the patient and it was learned that she had undergone cardiac catheterization in 1953, at which time the essential findings were as follows: the superior vena cava was widened, with evidence of arterialization in it; the left side of the mediastinal shadow was found to be due to an anomalous vein (presumably the common pulmonary vein leading to the left innominate vein); there was marked pulmonary hypertension; identical systolic pressures were found in the pulmonary artery, right ventricle, and brachial artery. Although these findings were considered to be evidence for a ventricular septal defect, and although this may be the case, they may also be the result of the marked pulmonary hypertension, the cyanosis occurring by a right-to-left shunt at the atrial level, an interatrial communication apparently being the more common finding in cases of total anomalous pulmonary venous connection.

This patient returned to the Clinic in April, 1955. She was found to be severely disabled by fatigue and dyspnea. On exercise in the laboratory with an ear oximeter in place, the percentage oxygen saturations were found to be: 76 per cent at rest; 40 per cent after 2 minutes' exercise on the treadmill, and 84 per cent after breathing 100 per cent oxygen for twelve minutes.

However, she felt that her disability was not sufficient to justify further catheterization or surgical correction at this time, and she returned home.

Fig. 5.—Case 4. Posteroanterior roentgenogram showing typical figure-of-eight configuration of the cardiovascular shadow in the type of total anomalous pulmonary venous connection under discussion. Note also the pulmonary vascular engorgement.

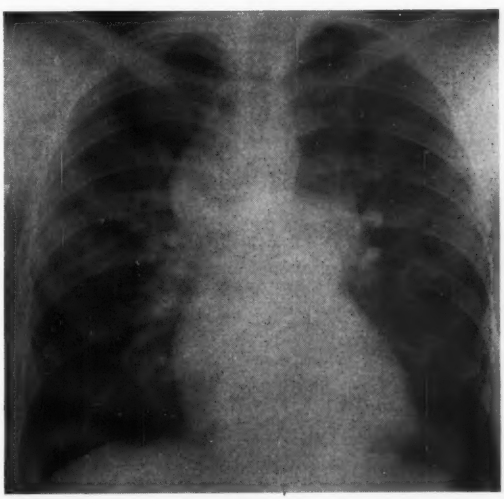

Fig. 6.—Case 5. The appearance of the cardiovascular shadow on this posteroanterior chest roentgenogram is characteristic of the figure-of-eight type of total anomalous pulmonary venous connection. Note also engorged pulmonary arteries.

This patient returned to the Clinic in January, 1956, and underwent cardiac catheterization. The findings were typical for the figure-of-eight total anomalous pulmonary venous connection with an atrial septal defect and severe pulmonary hypertension.

Comment.—This case is of interest in that the patient is by far the oldest living patient with this type of pulmonary venous anomaly to be described. In other respects her condition does not differ from that of the other patients whose cases are presented.

CASE 5.—A man, aged 18 years, entered the Clinic on Dec. 8, 1947, for consultation regarding a "tumor of the chest" which had been discovered when he tried to enlist in the Army two months previously. To his knowledge he had had no chest symptoms excepting some hemoptysis during the last six months. One month prior to his visiting the Clinic there had been an episode suggesting right hemiparesis with dizziness and inability to recognize anyone for a few days. He recovered completely in a few weeks and was feeling fine. A chest roentgenogram (Fig. 6) showed a bilateral superior mediastinal widening which on fluoroscopy was thought to be vascular. The branches of the pulmonary arteries in the lung fields were exaggerated and showed vigorous pulsation. An angiocardiogram was taken but the result was unsatisfactory. An electrocardiogram was interpreted as showing right ventricular hypertrophy. Atrial septal defect was considered, and it was thought that the hemiplegia might have been the result of a paradoxical embolism. A systolic murmur was heard in the third left interspace.

Although the diagnosis of an atrial septal defect seemed certain, the question of whether the superior mediastinal shadow was solid or vascular was not yet settled, and an exploratory operation was resorted to on Jan. 6, 1948. In the anterior mediastinum a large, ovoid, blue "mass" was found. It extended upward to the subclavian vein adjacent to the subclavian artery, overlay the arch of the aorta, and descended to the hilus of the lung anteriorly. It was tense and thin-walled, and blood could be seen swirling through it. Two vessels, apparently the two branches of the superior pulmonary vein on the left, entered this large vascular lesion. The pulmonary artery was twice as large as usual but was in the normal location.

The operation was terminated, and the patient recovered uneventfully.

Comment.—It seems, in the light of more recent knowledge about anomalous pulmonary venous return, that this patient almost certainly suffers from the "figure-of-eight" type of total anomalous venous connection. We have knowledge that this patient was still living in 1954, but do not know his clinical status.

Sepulveda and associates have presented a case of this type with a somewhat similar clinical picture: a woman, aged 42 years, who had at one time had roentgen treatment for a superior mediastinal "mass," and who also had had an episode of hemiplegia at the age of 28 years.

ANOMALOUS RIGHT PULMONARY VEIN

When most or all of the right lung drains into the inferior vena cava close to the region where the latter enters the right atrium (Fig. 7), various characteristic roentgenologic features may be seen to make one suspect the presence of this situation.

1. The anomalous vein can frequently be distinguished close to the right cardiac border. Near the diaphragm it becomes a single trunk, having collected branches from as high as the apex of the right lung. Invariably this vein can be beautifully demonstrated by tomographs.

2. Usually the heart will present prominently into the right hemithorax, and this is probably a reflection of an enlarged right atrium, this chamber receiving considerably more blood than it normally does. However, in certain cases it has been shown that this venous anomaly is accompanied by hypogenesis of the right lung, and in such cases it may be natural for the heart to be shifted to varying degrees into the right hemithorax.

3. It is not known in what percentage of these cases there are atrial septal defects. Of those patients who have been catheterized at the Mayo Clinic, one has had an atrial septal defect, while the other did not have the additional lesion. Judged by the appearance of the lung fields and the absence of clinical findings, it would seem that in the majority of cases there is not an atrial septal defect.

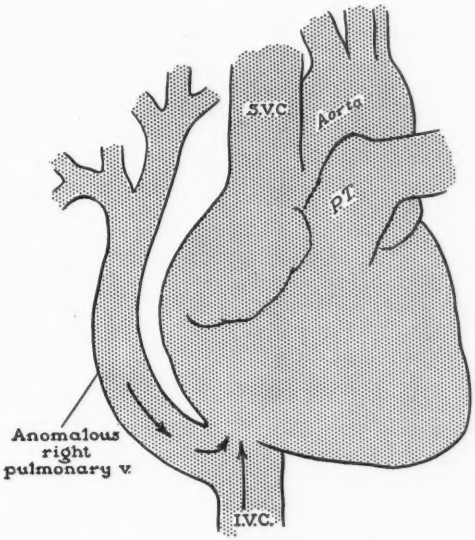

Fig. 7.—Diagram explaining the roentgen anatomy of the cases of anomalous venous connection of the right lung.

CASE 6.—A woman, aged 43 years, entered the Clinic because of a variety of complaints probably unrelated to her cardiac defect. Attention was drawn to the circulatory abnormality because the routine thoracic roentgenogram showed that the heart was predominantly in the right half of the thorax. The heart sounds were heard best to the right of the sternum; no murmurs were present. The physical examination otherwise showed no abnormal findings.

The thoracic roentgenogram was interpreted as probably indicative of agenesis of a portion of the right lung, with a large aberrant vessel in the basal portion of the right lung (Fig. 8, *a*). The anomalous vessel is well seen on the tomogram (Fig. 8, *b*). The trachea was situated to the right of the midline. The electrocardiogram was considered normal except that the precordial leads reflected the displaced position of the heart, with unusually high R waves in leads taken to the right of the sternum. At bronchoscopy it was noted that the patient had a very peculiar distribution of the bronchi of the right lung. It was first noted that the carina, instead of being in the anteroposterior direction, was

rotated clockwise so that the upper border was pointed at about 2 o'clock, while the lower was pointed in the neighborhood of 7 o'clock. The openings to the various branches of the right lower lobe were very wide and not in their normal position. The picture resembles that frequently seen associated with a bronchus going into a cystic area of the lung. The left side appeared perfectly normal.

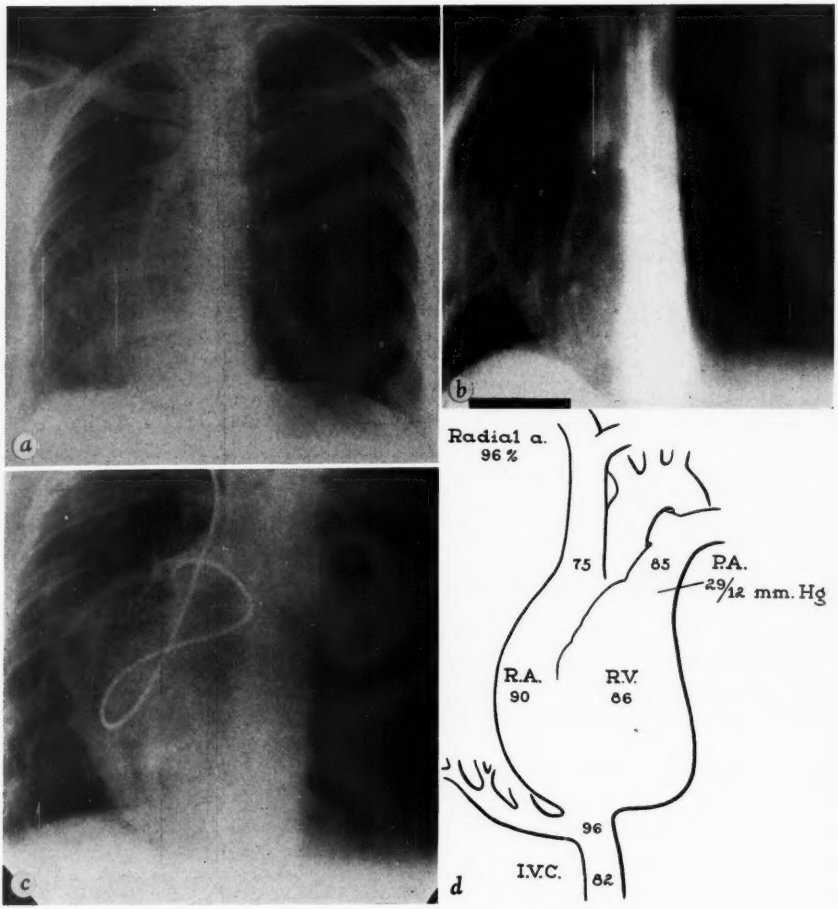

Fig. 8.—Case 6. *a*, Posteroanterior roentgenogram of a woman, aged 43 years, who has anomalous pulmonary drainage of the right lung to the inferior vena cava. Note the displacement of the heart into the right hemithorax; the anomalous vein can be detected through the heart shadow. *b*, A tomogram of this case demonstrates the anomalous vein very well. *c*, The tip of the cardiac catheter lies in the right pulmonary artery. An injection of Urokon sodium has been made, and the anomalous right pulmonary vein is beautifully demonstrated. *d*, Schematic representation demonstrating oxygen saturations found at various levels in the central circulation in Case 6.

A bronchogram was performed and revealed the left lung to be well developed; all bronchial segments could be identified. On the right side the upper lobe bronchus was seen for a distance of 1.5 cm., where it abruptly terminated. It appeared to be of larger caliber than normal. All of the segmental bronchi of the right middle lobe and right lower

lobe could be identified. The right main bronchus was pulled upward and somewhat posteriorly, and the right middle lobe appeared to supply the apex of the right thorax. Atelectasis or agenesis of the right upper lobe was diagnosed.

The main abnormality on cardiac catheterization was the high oxygen saturation of blood in the inferior vena cava at the diaphragmatic level. Blood of low oxygen saturation was obtained when the catheter was advanced slightly distally in the inferior vena cava. With the catheter in the right main pulmonary artery a 70 per cent solution of sodium acetrizoate (Urokon sodium) was injected into the artery; this medium rapidly outlined the anomalous right pulmonary vein coursing toward the inferior vena cava (Fig. 8, *c*).

A schematic representation of the central circulation in this patient illustrates the oxygen saturation of samples of blood taken from various sites within the heart and great vessels with the patient breathing room air (Fig. 8, *d*). The systemic arterial oxygen saturation was 96 per cent. The catheter could not be passed into the anomalous right pulmonary vein. The calculated recirculation was 30 per cent, expressed as the percentage of pulmonary flow that returned to the right side of the heart from the right lung. This correlates moderately well with the size of the right lung, approximately one-half of which was absent, as judged by bronchography.

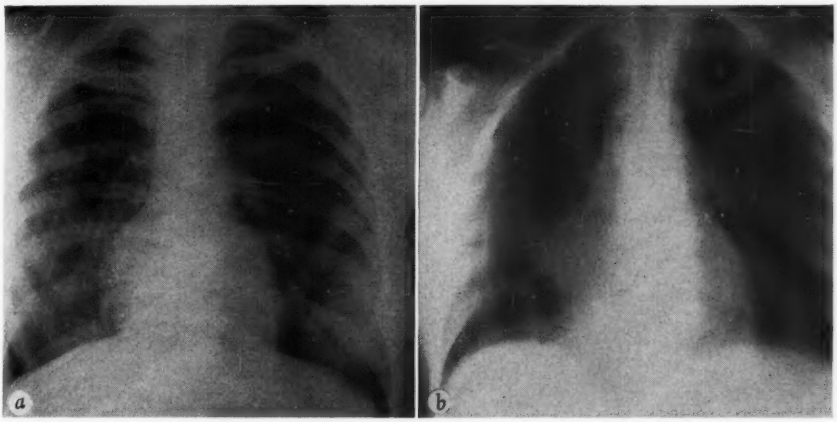

Fig. 9.—Case 7. *a*, The "streaky" appearance of the vessels along the right border of the heart and the slight shift of the heart into the right hemithorax suggest that further study should be done to exclude an anomalous vein in the right base. *b*, The tomogram confirms the presence of a large anomalous vessel in the right base, probably an anomalous vein draining the right lung.

CASE 7.—A woman, aged 26 years, came to the Clinic because of a question of pregnancy as well as the possibility of a congenital heart lesion. A chest roentgenogram (Fig. 9, *a*) revealed possible anomalous venous connection of the right lung, and tomograms (Fig. 9, *b*) confirmed the suspicion of a large anomalous vessel draining toward the inferior vena cava. The heart also projected more into the right hemithorax than it normally would, probably as the result of enlargement of the right atrium, but possibly also owing to hypogenesis of the right lung. Clinically, the right upper thorax was depressed and probably somewhat smaller than the left. A cardiologist evaluated the patient's cardiologic status with respect to the possibility of termination of pregnancy. There was not enough evidence of cardiac disability to justify such a measure, and the patient was advised to return after the birth of her child, for catheterization studies and possibly for a corrective operation.

CASE 8.—A girl, aged 11 years, was brought to the Clinic because of mental retardation. The routine chest roentgenogram was suggestive of an anomalous vessel in the right lung (Fig. 10, *a*). Tomograms confirmed this impression (Fig. 10, *b*) and suggested that the vessel drained toward the inferior vena cava. This patient had not had any pulmonary symptoms, and the cardiologist could not obtain any evidence of cardiac disability.

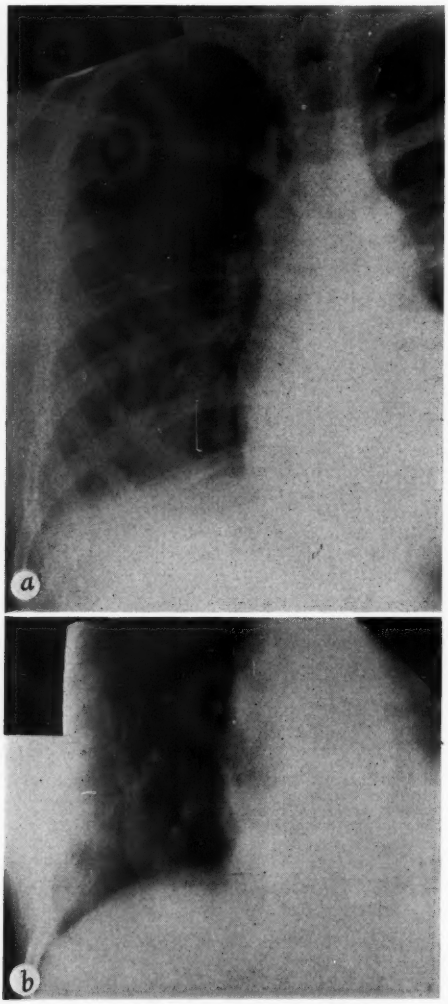

Fig. 10.—Case 8. *a*, Portion of posteroanterior chest roentgenogram of a girl, aged 11 years, showing anomalous vessel in the right base. *b*, The tomogram shows the anomalous vessel more clearly.

Comment.—In this case it was not possible to obtain catheterization studies or angiocardiography, so that the only "proof" of an anomalous venous connection of the right lung lies in the appearance of the roentgenogram and the fact that no other condition is known to cause this appearance.

CASE 9.—A woman, aged 53 years, accompanied a friend of hers to the Clinic and decided also to have a general examination. She had at times suffered from bronchitis, but had no specific or serious complaints. The results of her general examination were negative except that the chest roentgenogram revealed the presence of a large anomalous vessel on the right (Fig. 11, *a*), apparently an anomalous vein draining the blood from the right lung into the inferior vena cava near its entrance into the right atrium. This interpretation was confirmed by a tomogram (Fig. 11, *b*). The significance of the lesion, in the event of the occurrence of any future pathologic process of the left lung, was explained to the patient. She decided against an extensive cardiovascular investigation at the present time.

FIG. 11.—Case 9. *a*, Posteroanterior chest roentgenogram showing abnormal right paracardiac shadow which is due to an anomalous pulmonary vessel. There is also slight prominence of the heart in the region of the right atrium. *b*, Tomogram of the right lower portion of the chest clearly demonstrates the anomalous pulmonary vein, which drains toward the area where the inferior vena cava joins the right atrium.

CASE 10.—A woman, aged 43 years, had first been to the Clinic in 1926, at which time she had undergone tonsillectomy as well as an operation on the nose. In 1947, a cystadenocarcinoma of one of her ovaries had been removed elsewhere. She came to the Clinic later in 1947 and again in 1949 for postoperative evaluation. Her condition was satisfactory, and no evidence of recurrence could be detected. In 1931, a roentgenologist had remarked that the heart was rotated and displaced to the right. In 1947 the possibility of congenital heart disease was mentioned by the roentgenologist.

In 1952, she returned to the Clinic since she was nervous about a possible recurrence of the cystadenocarcinoma, but no such evidence could be found. At this time the roentgenologist remarked on what appeared to be an abnormal vessel in the right lung (Fig. 12). In 1954, this shadow was again noted, and anomalous venous connection of the right lung to the inferior vena cava was suggested. The cardiologist could find no evidence of significant heart disease at this time, and the patient did not want to remain for further cardiovascular studies.

Comment.—The roentgenologic findings in this case are similar to those in cases previously described in the literature. Although physiologic proof is lacking, it would be surprising if this were not a case in which anomalous venous connection of the right lung to the inferior vena cava existed.

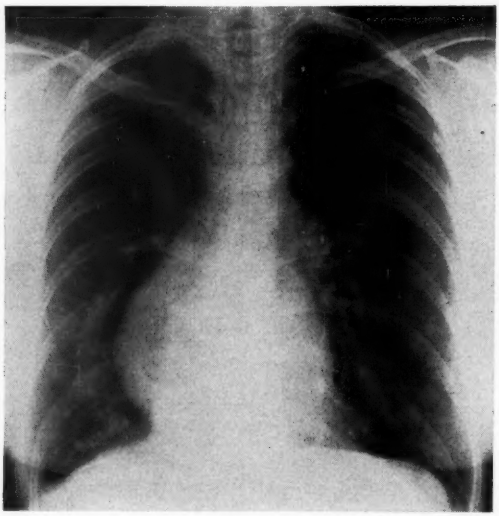

Fig. 12.—Case 10. Posteroanterior chest roentgenogram illustrates the large anomalous vessel in the right lower portion of the chest, which is undoubtedly an anomalous right pulmonary vein draining into the inferior vena cava. As a result of this the right atrium is larger than normal, and projects into the right side of the chest farther than it normally would.

COMMENT

In a paper on total anomalous pulmonary venous drainage, Whitaker reported on 6 cases, 3 of which were found early in 1953, and he remarked that this "suggests that this anomaly is not so rare as the published cases indicate. When it is widely known that the radiological features are sufficiently characteristic to allow the anomaly to be recognized at routine examination there will probably be an increase in the frequency of its diagnosis. . . ." There seems to be considerable truth in this statement. The patients having total anomalous connection on whom data are presented in this communication were all examined, or re-examined in view of recent knowledge, within the last year. Undoubtedly there are other cases in our files which have been regarded as tortuosity of the aorta or a mediastinal mass. We have made no attempt to unearth them.

It is of interest from the point of view of differential diagnosis that, in a child, the thymus may cause a shadow on the posteroanterior chest roentgenogram which is identical with the figure-of-eight picture. The lateral view is probably of differential diagnostic value, for in the cases of total anomalous

venous connection that my colleagues and I have seen, the anterior mediastinum has been clear, whereas if an "abnormal" shadow is due to the thymus, the anterior mediastinum will not be clear.

Furthermore, although theoretically a case of total anomalous venous connection (in which there is optimal division of blood at the atrial level) may show normal vascular markings, in practice all the roentgenograms of patients that we have seen have shown evidence of vascular engorgement such as is seen in cases of recirculation. For the present, therefore, increase in the peripheral pulmonary arterial markings should be regarded as an essential part of the roentgenologic diagnosis.

It is of interest that in all the cases in our group in which there were adequate physiologic data there has been marked pulmonary hypertension. In view of newer techniques in surgery, it therefore behooves the roentgenologist to be familiar with this condition, since it is potentially correctable, and probably preferably so in the younger years of life.

With respect to the cases presented in this paper as anomalous venous connection of part or all of the right lung to the inferior vena cava, it is admitted that in only one case was physiologic proof obtained. However, in view of the fact that several proved cases have been presented in the literature and that all of these have had identical roentgenologic findings, and of the fact that no other condition is known to give this appearance, there is sufficient justification to add the physiologically unproved cases. This is done with the intent of drawing further attention to these cases, since they are probably less rare than previously thought. The cases presented have all been collected within the last two years.

The roentgenologic findings in cases of anomalous venous connection of the right lung to the inferior vena cava are sometimes less obvious than in cases of total anomalous pulmonary venous connection, but there are several features which may bring to mind the possibility: (1) The heart usually, but not always, projects into the right hemithorax more than it normally would. In some cases it is even totally rotated into the right side of the chest. (2) The right hemithorax may be slightly smaller than the left, and bronchograms in such cases may show hypogenesis or agenesis of a portion of the right lung. (3) The anomalous vein may be seen coursing as a saber-shaped shadow along the right paracardiac region. If tomograms are obtained, it will be seen to start as small tributaries, sometimes from as high as the apex; these gradually merge and eventually a large main trunk is seen which courses in the general direction of the right cardiophrenic angle. Even if the main vein cannot be seen on the routine posteroanterior film, its presence should be suspected if the pulmonary vascular markings along the right border of the heart appear unusual in that they seem to taper *toward* the hilus. Bucky films are usually not particularly effective in clarifying the picture, but tomograms may be dramatic.

Some of these cases are associated with an atrial septal defect. In one such case the atrial septal defect was corrected and the anomalous vein transplanted into the left atrium. This case is not presented here because the huge

size of the heart prior to operation obscured the area of the anomalous vein entirely. After correction the heart size decreased by almost one half. Other cases—and probably the majority—are unassociated with an interatrial communication. This statement is based on the cases presented in the literature, as well as on the fact that in most of our cases there were no evidence of recirculation in the lung fields and no obvious cardiac disability. One such case with physiologic proof is presented. In another case, however, the clinical picture did suggest the presence of an atrial septal defect.

These cases are of interest in that they are within the realm of surgical correctability. It would be difficult to urge such a patient to undergo operation, because the condition is usually subjectively symptomless. However, to put the physiologic problem crudely, if such a patient were at any time to have pneumonia of the left lung, or for some reason underwent left pneumonectomy, death would be inevitable, since the right lung would not be able to contribute sufficient oxygenated blood to the systemic circulation even if an atrial septal defect were present.

SUMMARY

Cases are presented of the two types of anomalous pulmonary venous connection which are readily recognizable on the routine posteroanterior chest roentgenogram. These are (1) the "figure-of-eight" type of total anomalous pulmonary venous connection, and (2) anomalous venous connection of the right lung to the inferior vena cava.

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USE OF A NEW TOPICAL ANESTHETIC AGENT (DYCLONE) IN PERORAL ENDOSCOPY

A Report of 569 Procedures

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A TOPICAL anesthetic agent which is potent, fast, nonirritating and nonsensitizing is highly desirable for peroral endoscopy. No known agent which is ideal in all of these respects is available so that newer drugs are constantly being evaluated. Dyclone* has been used in procedures in this institution; this work forms the basis for this report.

Dyclone (4n-butoxy-beta-piperidino propiophenone hydrochloride) is a white crystalline powder with the additional advantages of bactericidal and fungicidal properties.[1, 2] The compound, with the generic name of dyclonine HCl, is soluble at a 2 per cent concentration in water which is slightly acidic and stable in this solution. Animal studies have shown good topical anesthesia in the cornea for 50 to 60 minutes without irritation. There is said to be no demonstrable parasympatholytic action and no change in the response to acetylcholine or epinephrine of the cardiovascular or gastrointestinal systems.[1, 2] To date, the incidence of allergic reactions to the agent is about 0.05 per cent of all cases, the majority of which occurred in the topical application of Dyclone cream. In thousands of cases in which Dyclone solution has been used in the eye, mouth, bronchi, and urethra, no sensitivity has been reported. Using *Staphylococcus aureus* as the test organism, the absolute phenol coefficient is 3.6.[3]

In these studies, using a standard technique with Jackson cross-action forceps the soft palate, tonsils, pillars, pharynx, and pyriform sinuses were swabbed with cotton which had been saturated in either 0.5 or 1 per cent solution. Approximately 7 c.c. was used for this stage. Under indirect laryngoscopy, about 10 c.c. of 0.5 per cent solution in 1 to 2 c.c. aliquots was injected into the larynx and trachea for bronchoscopies and bronchograms. For esophagoscopies and esophageal dilatations, the patient swallowed a similar amount of the 0.5 per cent solution. The time required for good anesthesia was about 6 minutes. The anesthesia generally lasted from 30 to 45 minutes which was adequate time for performance of the desired examination yet brief enough to allow recovery from the anesthesia before leaving the clinic.

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*(dyclonine HCl)—Pitman-Moore Company, Indianapolis 6, Ind.

A total of 400 patients was anesthetized in the above-described manner and 569 procedures were performed. The types of procedures are listed in Table I. No procedure was abandoned because of inadequate anesthesia. No

TABLE I

Bronchograms	182
Bronchoscopies	313
Esophagoscopies	39
Esophageal dilatations	35
Total procedures	569

untoward reactions were encountered with the exception of one instance, a 27-year-old, white, frightened nurse who complained of vertigo, sharp lancinating pain in both ears, paresthesia (tingling) of the hands, and acute dyspnea. There was no change in blood pressure, and pupil reaction and tendon reflexes were normal during this episode which lasted for approximately fifteen minutes and subsided spontaneously with no treatment. A similar reaction occurred on the ward when this patient had no anesthesia. This would indicate that this episode was a manifestation of hysteria.

Recently, we have used Dyclone to alleviate the pain of esophagitis in 15 patients receiving deep x-ray treatment for nonresectable carcinoma of the lung. Fifteen minutes ante cibum, 5 c.c. of Dyclone 1 per cent is placed in the oral pharynx and the patient swallows the drug. We have found that the pain of swallowing food is alleviated partially or entirely with this regimen but the patients complain of inability to taste the food and numbness of the tongue.

One patient has been anesthetized thirty-five times for esophageal dilatation at intervals of one week. To date, no evidence of any toxic effect has been determined. Liver and renal function tests are normal; peripheral and bone marrow blood studies are normal.

SUMMARY

A total of 400 patients were locally anesthetized with 1 per cent and 0.5 per cent Dyclone with prompt, adequate anesthesia for peroral endoscopy.

No untoward reactions or toxic effects were noted in this series.

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Announcements

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Notice of Annual Meeting

The Thirty-seventh Annual Meeting of The American Association for Thoracic Surgery will be held May 4, 6, and 7, 1957, in Chicago, Illinois. Headquarters will be at the Palmer House.

Requests for Hotel Reservations

These should be mailed directly to Mr. Edward Langford, Reservations Manager, Palmer House, Chicago. Please mention this Association, the type of accommodation desired, the date, and approximate hour of arrival and departure. If accommodations are desired elsewhere in Chicago, please communicate directly with the hotel of your choice.

Thoracic Surgery Forum

The Thoracic Surgery Forum will be continued as a special session at the 1957 meeting. The Forum is primarily for the presentation of short papers on current thoracic research, experimental problems, anatomical studies, and modified or new surgical techniques. The inclusion of any considerable amount of clinical material in these reports makes the choice more difficult and the Program Committee reserves the right to reject such papers, or to suggest their transferal to the Regular Program.

Papers at this session will be limited to ten minutes, including the showing of lantern slides or other illustrative material. At the discretion of the President, three minutes may be allowed as the maximum discussion for each paper.

All Thoracic Surgery Forum papers will be published together in one issue of the JOURNAL. Maximum length: 3000 words without illustrations. If illustrated, an appropriate number of words must be subtracted for each cut used.

Abstracts of Papers

Abstracts of all papers for presentation at the 1957 meeting must be received on or before Dec. 15, 1956, otherwise they will not be considered by the Program Committee.

Abstracts should be labeled "For Thoracic Surgery Forum," or "For Regular Program." The abstracts should contain from 200 to 250 words and accurately reflect the contents of the completed paper.

Five, repeat, five copies of *each* abstract must be sent to Miss Ada Hanvey, Administrative Assistant, The American Association for Thoracic Surgery, 600 South Kingshighway, St. Louis 10, Missouri.

Those on the program are reminded that papers presented at the meeting *must* be handed to the secretary immediately after their presentation. If they are not ready at that time there is a chance that they will not be published in THE JOURNAL OF THORACIC SURGERY.

Motion Picture Session

Provisions have been made to show a limited number of motion pictures to be selected on a competitive basis. ***The films themselves,*** together with descriptive material concerning length of presentation, etc., must be received by Dr. Karl P. Klassen, The Ohio State University, Columbus 10, Ohio, before Dec. 15, 1956.

It is planned to run the motion pictures in a smaller room at the same time as the scientific sessions. If the films are well labeled, it will not be necessary for the author to be present for comment.

Applications for Membership

Applications for Associate Membership in the Association must be received by the Membership Committee not later than Dec. 15, 1956, otherwise the application will be deferred for consideration until the 1958 meeting.

Applicants must be sponsored by three Active or Senior Members of the Association. In addition to the signatures on the application form, the sponsors will forward a *separate* letter concerning the applicant directly to:

Dr. O. T. Clagett
Chairman of the Membership Committee
Mayo Clinic
Rochester, Minn.

Sponsors are reminded that *new* letters of recommendation must be forwarded to the Membership Committee should their applicants be held over for reconsideration a second year. The new letters of recommendation should also be sent to Dr. Clagett, the Chairman of the Membership Committee.

Erratum

Through an error the name of Dr. Joseph L. Mangiardi of 426 Pennsylvania Avenue, Freeport, New York, was omitted from the list of Associate Members published in the June issue of this JOURNAL. It will be added to reprints of the official list of members.